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Bowline Point Generating Station Entrainment Abundance and Survival Studies

1979 ANNUAL REPORT with OVERVIEW of 1975—1979 STUDIES

Prepared for:
Orange and Rockland Utilities, Inc.

Prepared by:
ECOLOGICAL
ANALYSTS,
INC.

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BOWLINE POINT GENERATING STATION ENTRAINMENT ABUNDANCE AND SURVIVAL STUDIES

1979 ANNUAL REPORT WITH OVERVIEW OF 1975-1979 STUDIES

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CONTENTS

CONTENTS (CONT.)

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CONTENTS (CONT.)

LIST OF FIGURES

LIST OF FIGURES (CONT.)

LIST OF FIGURES (CONT.)

LIST OF FIGURES (CONT.)

LIST OF FIGURES (CONT.)

LIST OF TABLES

1. INTRODUCTION

1.1 STUDY PROGRAM

The Bowline Point Generating Station uses a once-through cooling system to dissipate waste heat. In the cooling process, water from the Hudson River is pumped through condensers where heat is transferred from the exhaust steam to the cooling water; the warmed water is then returned to the river. The two electrical power generating units at Bowline Point withdraw up to 1,452 m^3/min (384,000 gallons per minute) of water from the Hudson River for cooling purposes. Aquatic organisms small enough to pass through the intake screens (9.5-mm bar mesh) may be carried through the cooling water systems (pumped entrainment) where they are exposed to abrupt changes in temperature and hydrostatic pressure, mechanical buffeting, and velocity shear forces. Determination of the abundance and survival of these entrained organisms is an important step in realistically assessing the potential ecological effects of power plant operation on the aquatic environment.

Ecological Analysts, Inc. (EA) assessed entrainment effects at the Bowline Point plant at the population and ecosystem level between 1975 and 1979. These studies concentrated on the major components of the aquatic food web which may be subject to entrainment during part or all of their life cycle. The aquatic community of the Hudson River is primarily a detrital-based food web with energy inputs from watershed, terrestrial, and pollution inputs (McFadden 1977). Primary producers (phytoplankton, periphytic algae, and aquatic vascular plants) are limited by the high turbidity and, therefore, shallow light penetration in the estuary. Consequently, photosynthesis is generally restricted to the shallow surface zone (the upper 1-2 m). While phytoplankton do not play a major role in the overall energy budget of the Hudson River estuary, the group may be an important food source for some higher trophic levels. Therefore, in conjunction with near-field distribution and abundance studies (EA 1978a, ORU 1977), the effects of entrainment on phytoplankton were evaluated with respect to their role as primary producers during 1975 and 1976.

Zooplankton serve as a middle link in the transfer of energy and materials through the food web. These organisms feed on both algae and detrital particles and subsequently provide food for higher trophic levels (other aquatic invertebrates and fish). Because of differences in size, abundance, and trophic relationships, zooplankton were separated into micro- (less than 1 mm) and macrozooplankton and ichthyoplankton during these studies. Microzooplankton (e.g., copepods, cladocerans, and gastropod veligers) survival was examined during 1975 and 1976. Macrozooplankton (e.g., *Gammarus* spp. and *Neomysis*) survival was studied during 1975, 1976, and 1978, with the major emphasis on the most abundant taxa. Abundance and survival of ichthyoplankton were monitored during the primary spawning and nursery periods from 1975 through 1979.

Survival studies were conducted at the plant discharge and intake using a treatment-control experimental design. Intake samples provide an estimate of mortality associated with sampling stress while discharge samples are subject to entrainment and sampling stress. During 1975-1979, access to the discharge was gained through a standpipe approximately 600 m from the end of the discharge pipe. However, modifications to the sampling gear permitted access to the offshore submerged discharge diffuser during 1978 and 1979 to evaluate entrainment effects at the terminus of the cooling water system. To assess latent mortality which might result from entrainment, organisms were held under ambient conditions. Similar to standard procedures for toxicity bioassays, this holding period was extended to 96 hours for macrozooplankton and ichthyoplankton. Comparison of intake and discharge samples provided a means for estimating entrainment survival. When examination of the intake and discharge survival curves indicated that a difference existed (latent effect), entrainment survival estimates were based on the time at which the latent effect is manifest. Because of the short generation time for many of the phytoplankton and microzooplankton taxa the latent-effects holding period was shortened to 24 hours.

Early ichthyoplankton abundance studies were conducted using 0.5-m conical plankton nets at the intake. However, inherent difficulties of using nets to sample planktonic populations at power plant intakes (i.e., low tow speed, stratification and patchiness of organisms, limitations on net size imposed by the intake structure, and dependability of sample volume measurements) led to the development (EA 1977a) of an automated pumped abundance sampler (AUTOSAM; U.S. Patent No. 4, 145, 928) which was subsequently used from 1977 through 1980 to sample from the plant discharge pipe.

1.2 SCOPE OF REPORT

A series of reports (EA 1976, 1977b, 1978c, 1978d, 1979a) have detailed studies conducted annually between 1975 and 1978. The objective of this report is twofold: (1) to provide an analysis of the 1979 studies on a level of detail comparable to the previous annual reports, and (2) to provide a summary analysis of the 5-year program of studies. Although some data summaries for 1975 through 1978 are provided in the subsequent chapters and appendixes, the reader is referred to the earlier annual reports for more detailed information.

The analytical chapters in this report have been separated by trophic group:

Chapter 4 - Phytoplankton
Chapter 5 - Invertebrate Zooplankton
Chapter 6 - Ichthyoplankton

The ichthyoplankton chapter provides a summary of the 1979 studies and an overview of the 1975 through 1979 studies for entrainment abundance and entrainment survival.

2. SUMMARY

Studies were conducted by Ecological Analysts, Inc. between 1975 and 1979 to evaluate the effects on the aquatic community of entrainment in the once-through condenser cooling water system at the Bowline Point plant. This evaluation examined effects at various trophic levels, including phytoplankton, invertebrate micro- and macrozooplankton, and ichthyoplankton. These studies have generally demonstrated small initial reductions in survival and/or productivity as a result of mechanical stresses of entrainment and negligible susceptibility to thermal stress under normal plant operating conditions.

Analyses of various population and productivity parameters indicate that phytoplankton (which account for less than 1 percent of the energy budget for the lower Hudson River estuary) entrained at the Bowline Point plant may exhibit an initial 20-27 percent reduction in primary productive capacity at discharge temperatures below 33.5 C (the maximum temperature observed during these studies). No relationship between temperature and survival or productivity was observed at discharge temperatures in this range. The high reproductive rate and short generation time, typical of many phytoplankton, resulted in a rapid recovery of the community in the 24 hours following entrainment. It is possible that the sublethal temperature elevations experienced during entrainment may stimulate recovery of the community from the effects of mechanical stress. As a result of this recovery rate one would not expect to encounter any localized reductions or shifts in community composition as a result of entrainment, an observation supported by near-field surveys conducted in the vicinity of the Bowline Point plant and thermal plume (ORU 1977 and EA 1978a).

Invertebrate microzooplankton (an important link in the transfer of energy between the producers and higher trophic consumers--e.g., fish larvae and juveniles) exhibited negligible entrainment effects during 1975 and 1976. While initial reductions of less than 16 percent were observed for the most abundant taxa, the high reproductive rates resulted in recovery to pre-entrainment densities within 48 hours following entrainment. Any mortality observed below 35 C could be attributed to mechanical stresses of entrainment. Since discharge temperatures above 35 C are rarely observed, no appreciable thermal mortality is anticipated.

Gammarus spp., Neomysis americana, Chaoborus punctipennis, and Monoculodes edwardsi were generally the most abundant macroinvertebrates entrained in 1975, 1976, and 1978. Significant differences in survival among years observed for these major species reflected changes in the sampling design and schedule. Initial survival of these four taxa was generally not reduced at the discharge as a result of entrainment; however, delayed mortality (within 24 hours) resulting from entrainment produced significant reductions in discharge survival for Gammarus spp. and Neomysis. Entrainment survival (S_e) typically exceeded 90 percent when discharge temperatures were below the lethal thresholds of the major macrozooplankton taxa. Survival of Gammarus spp. at the discharge was slightly higher during the two-pump full operating mode (97 percent) than during two-pump throttled (90 percent). Too few organisms were collected to evaluate the effects of circulator pump operation on survival of other taxa.

Thermal mortality is negligible for most of the major macrozooplankton taxa, since discharge temperatures at Bowline Point rarely exceed the TL50 for most of these taxa. A slight decrease in survival (approximately 5 percent) was observed between 34 and 36 C for Gammarus spp. in 1975; however, no such decrease was observed in 1976 and 1978. Neomysis exhibited a sharp decrease in survival between 32 and 35 C with a median tolerance limit (TL50) of 34.8 C. The laboratory-predicted TL50 for thermal effects was 33.7 C (EA 1978b) for conditions simulating entrainment exposure. No temperature effects were observed for Monoculodes or Chaoborus which have TL50s of 36 C (Lauer et al. 1974) and 42 C, respectively.

The most abundant ichthyoplankton taxa entrained at the Bowline Point plant are bay anchovy, Atlantic tomcod, white perch, and striped bass. Peak abundance for each species was generally observed for larvae near the yolk-sac to post yolk-sac transition. The time and duration of this peak is influenced primarily by ambient river temperature and the rate of the spring temperature rise which effects the time of spawning and growth for striped bass and white perch. The period of larval development for Atlantic tomcod (a winter spawner) is more extended than for the two Morone species and abundance was influenced more by movement of the estuarine salt front and their distribution relative to that front. Peak bay anchovy spawning occurs in the higher salinity regions downstream of the Bowline Point plant and their abundance in entrainment samples is primarily a function of the extent and timing of the summer salt intrusion into the middle estuary.

Comparison of the densities of entrained striped bass and white perch and regional river populations indicates that exposure of these two species to entrainment may be limited by their riverwide and local distribution. Surveys by Texas Instruments, Inc. (TI) indicate that, during most of the entrainment season, 60 to 90 percent of the entrainable population of these two species is generally outside of the 12-mile river region in which the Bowline Point plant is located. Furthermore, peak entrained densities of these two species were much lower than those in the Croton-Haverstraw Bay region. Although plant densities of striped bass were similar to the less dense shoal strata and Bowline Pond transects, white perch were still less abundant in the plant than in the shoal or pond.

The exposure of entrained ichthyoplankton to thermal stress during entrainment is limited by their seasonal and diel distribution. The peak period for the most abundant species and life stages typically occurs well before the discharge temperatures reach the lab predicted TL50s (median tolerance limit) for these taxa. In addition, abundance is generally highest between 2100 and 0600 hours when the plant usually operates at less than 70 percent capacity, thus limiting the delta-T experienced by entrained ichthyoplankton.

The sensitivity of striped bass and white perch to mechanical entrainment stress decreased as length increased. Survival of striped bass exceeded 90 percent for fish greater than 11 mm. The importance of this fact for impact assessment is that survival of entrained striped bass approaches 100 percent for the life stages (late post yolk-sac and early juvenile) during the period that year class strength is set (TI 1980a). While survival of both striped bass and white perch less than 8 mm was higher during plant operation with two pumps in the throttled mode than in the full mode, differences for larger larvae were not apparent.

No consistent decrease in mortality resulting from thermal exposure was observed for striped bass or white perch collected between 30 and 33 C (in the range of the thermal mortality threshold for these species). However, sharp decreases in survival did occur above 33 C, as temperatures approach the laboratory predicted TL50. Similar to the response of larvae to mechanical stresses observed in these field studies, laboratory studies have shown an increase with length in the resistance of larvae to thermal stress (Cada et al. 1980; EA 1978b, 1979b). This fact, as suggested by the abundance studies, is important for impact assessment since few larvae are collected near or above 33 C and most larvae collected in this temperature range are in the larger, more tolerant length groups. Therefore, the susceptibility of entrained striped bass and white perch to thermally induced mortality is negligible.

Few Atlantic tomcod were collected above their incipient lethal temperature and survival of mechanical stresses during entrainment exceeded 93 percent.

Ichthyoplankton survival studies conducted between 1975 and 1979 concentrated on survival of entrainment in the once-through cooling water system as reflected by sampling at the Bowline Point discharge standpipe. Sampling at the standpipe occurs approximately 600 m prior to discharge into the river through the submerged offshore high velocity diffuser and studies conducted in 1978 and 1979 generally indicate that no significant decrease in survival occurs as a result of transit between the standpipe and diffuser or discharge through the diffuser.

3. STUDY SITE

3.1 SITE DESCRIPTION

The Bowline Point Generating Station is situated on the west bank of the Hudson River estuary, approximately 60 km (37.5 mi) north of the southern tip of Manhattan. This is the widest point in the river and is characterized by a relatively narrow shallow channel with wide shoal areas bordering each shore.

Flow rates at this location, as in the lower estuary in general, are controlled predominantly by the tides. The tidal flow has an average rate of 5,000 m^3/sec compared with the freshwater discharge rate which ranges from a monthly mean of about 175 m^3/sec during the summer drought to 1,750 m^3/sec during spring freshet.

Condenser cooling water is withdrawn from a small embayment of the estuary known as Bowline Pond and returned directly to the Hudson River through an offshore jet diffuser (Figure 3-1). Bowline Pond has a surface area of 490,000 m^2. The maximum depth in the pond is 12-15 m. Pond water exchanges with river water through a small inlet, 60 m wide with a maximum depth of 3-4 m.

Physicochemical variables, such as water temperature and conductivity, influence the temporal and spatial occurrence of ichthyoplankton, invertebrate zooplankton, and phytoplankton. The seasonal ambient river temperature profile in the vicinity of Bowline Point is typical of a temperate estuary. Daily water temperatures recorded at the Bowline Point plant intake reflect this pattern although they are occasionally influenced by recirculation of water from the discharge. (Figure 3-2 depicts 1979 water chemistry data as an example of annual trends.*) Because of its physical connection with the estuary, the pond is also subject to salinity intrusion. Salinity of the Hudson River near the Bowline Point plant ranges from fresh water to approximately 8 ppt. Since the Bowline Point plant is located in the transitional portion of the estuary, conductivity is highly variable depending on freshwater flow and tidal mixing (Figure 3-2; Table A-1 in Appendix A). Dissolved oxygen readings generally reflect the effect of seasonal ambient temperature variation on the solubility of oxygen in water (Figure 3-2 and Table A-1). The pH is relatively stable and ranges from 6.0 to 8.4 (Figure 3-2 and Table A-1).

3.2 THE POWER PLANT

The Bowline Point plant consists of two completely enclosed oil- or gas-fired steam-electric units, each having a net generating capability rating of 600 MWe and a gross capability of 622 MWe (Table 3-1). Unit 1 began commercial operation in September 1972 and Unit 2 began commercial operation in May 1974.

Each unit has a separate once-through cooling water system. The cooling water is pumped from an intake structure located on Bowline Pond (Figure 3-1). Each

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* Similar water chemistry data at the Bowline Point Plant can be found in EA 1976, 1977b, 1978d, 1979a.

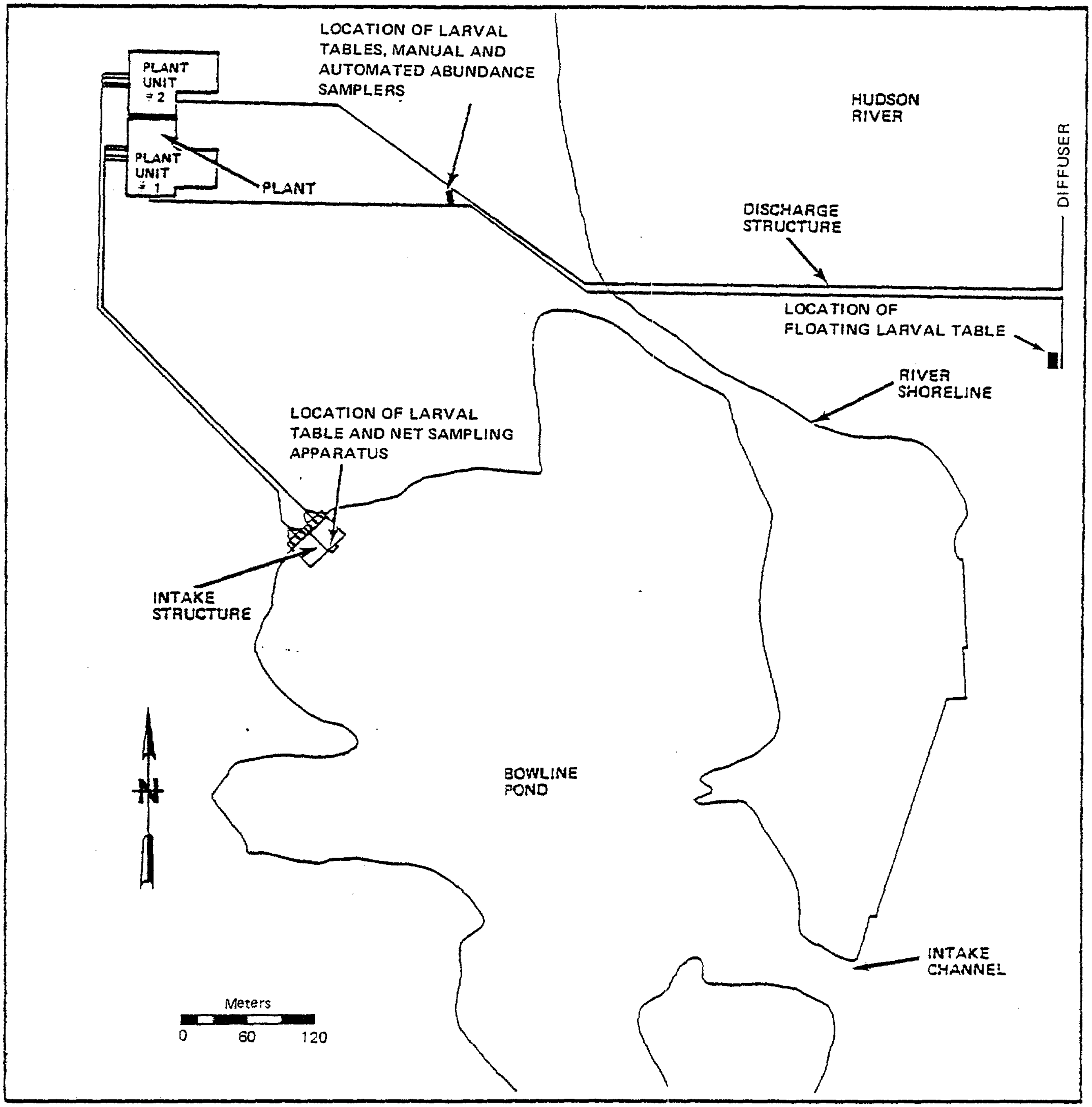

Figure 3-1. Diagram of Bowline Point plant site.

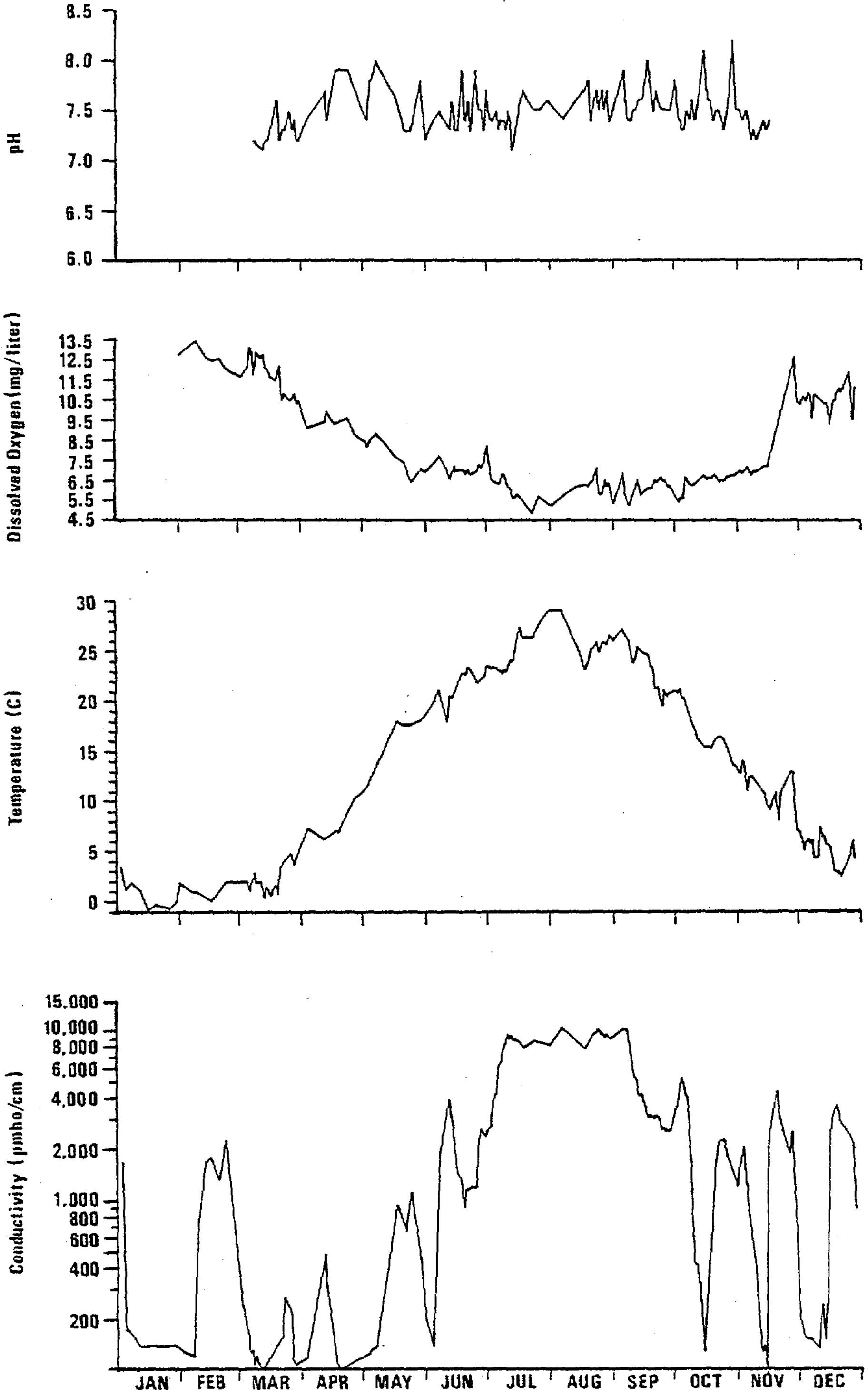

Figure 3-2. Physicochemical parameters taken at the Bowline Point plant intake during 1979.

TABLE 3-1 PLANT DESIGN DATA FOR EACH UNIT OF THE BOWLINE POINT PLANT

Generator Characteristics	
Maximum generating capacity	620 MWe
Cooling water flow rate:	
Condenser (maximum)	23.7 m^3/sec (375,000 gpm)
Service	0.5 m^3/sec (8,500 gpm)
Intake Characteristics	
Maximum approach velocity to screens	0.23 m/sec (0.77 fps)
Pipe diameter from intake to condenser	3.2 m (10.5 ft)
Length of intake tunnel:	
Unit 1	400 m (1,310 ft)
Unit 2	470 m (1,540 ft)
Tunnel velocity (maximum)	3 m/sec (10 fps)
Discharge Characteristics	
Total length of discharge tunnel:	
Unit 1	860 m (2,820 ft)
Unit 2	875 m (2,870 ft)
Pipe diameter from condenser to discharge ports	3.2 m (10.5 ft)
Tunnel velocity (maximum)	3 m/sec (10 fps)
Length of diffuser	67 m (220 ft)
Number of diffuser ports	8
Initial jet velocity	4.6 m/sec (15 fps)

intake bay is approximately 5 m (16 ft) wide and equipped with a bar trash rack, a 9.5-mm mesh vertical traveling screen, and a 700 m^3/min (185,000 gpm) circulating water pump. The circulating water pumps for each unit can be operated individually or in combination. Circulating water flow and approach velocities at the bar racks vary with pumping mode:

Number of Pumps Operating	Total Flow at Mean Water Elevation m^3/sec (gpm)	Intake Approach Velocity m/sec (fps)
3	24.2 (384,000)	0.23 (0.77)
2	20.0 (316,000)	0.18 (0.59)
2 (throttled)	16.2 (257,000)	0.15 (0.49)

The units normally operate in one of three modes of pump operation: two pumps throttled (140 x 10^4 m^3/day), two pumps full (172 x 10^4 m^3/day), or three pumps full (209 x 10^4 m^3/day).

The circulating water is pumped through the condensers where the excess heat of the system is transferred to the cooling water. The maximum condenser cooling water flow is 24.2 m^3/sec (384,000 gpm). The circulating water is returned to the Hudson River about 400 m from the river shoreline where dispersion of the heated waters is effected by passage through submerged, multiport, high-velocity diffusers constructed perpendicular to the river flow.

Temperature elevations in the circulating water system are a function of generating load and coolant flow. For a given rate of heat rejection, an increase in cooling-water flow will decrease the transit time through the system and the delta-T to which the entrained organism is exposed. Maximum temperature/time regimes of exposure for standard pumping modes (Table 3-2) vary only slightly between Unit 1 and Unit 2. Electrical output required from Bowline Point is dependent upon electrical demands and, for this reason, temperature elevations observed in the condenser cooling water are generally lower than the predicted values.

TABLE 3-2 CALCULATED MAXIMUM TIME-TEMPERATURE REGIMES OF EXPOSURE DURING TRANSIT THROUGH THE BOWLINE POINT PLANT COOLING WATER SYSTEM

		Unit 1			Unit 2		
Number of Pumps Operating	System Section	Transit Time τ (min)	ΔT (C)	$\int_0^\tau \Delta T\,dt$ (C-min)	Transit Time τ (min)	ΔT (C)	$\int_0^\tau \Delta T\,dt$ (C-min)
3	Intake - condenser feed	2.2	0.0	--	2.6	0.0	--
	Condenser feed - effluence	5.3	8.3	44.0	5.4	8.3	44.8
2	Intake - condenser feed	2.7	0.0	--	3.1	0.0	--
	Condenser feed - effluence	6.4	9.8	62.7	6.5	9.8	63.7
2 (throttled)	Intake - condenser feed	3.3	0.0	--	3.9	0.0	--
	Condenser feed - effluence	8.0	12.1	96.8	8.1	12.1	98.0

4. EFFECT OF ENTRAINMENT ON PHYTOPLANKTON

4.1 INTRODUCTION

This chapter summarizes studies conducted at the Bowline Point Generating Station in 1975 and 1976 to evaluate the effects of entrainment on phytoplankton. Phytoplankton productivity constitutes only about 0.24 percent of the primary input to the energy budget of the lower Hudson River (EA 1978a) while terrestrial watershed and pollutional input contribute 99 percent. Although phytoplankton may contribute minimally to the total energy budget of the estuary their potential value to species or life stages at higher trophic levels makes evaluation of phytoplankton entrainment important.

These studies were conducted to determine the survival and primary productive capacity of the total phytoplankton community entrained into the cooling water system of the Bowline Point plant. Numerous parameters have been examined addressing the effects of entrainment on phytoplankton. Most of these parameters address the effects of entrainment of phytoplankton and their role as producers (converting soluble inorganic molecules into organic material through photosynthesis using sunlight as an energy source). Parameters related to this photosynthetic role include primary productivity rate (measured by carbon-14 uptake); levels of essential photosynthetic pigments (chlorophyll a); and levels of cellular adenosine triphosphate (ATP, the internal energy source for photosynthesis and other metabolic functions). When these parameters are considered in conjunction with abundance and measures of condition (fluorescence microscopy) they provide a basis for the evaluation of entrainment effects. The parameters monitored during each year are listed in Table 4-1.

4.2 METHODS

If the sampling procedures used at the intake (control) and discharge are the same, consistent differences observed between the two stations can be assumed to result from entrainment. Since recirculation of cooling water can range from 11.6 to 14.8 percent (LMS 1978, EA 1977d), a control station in the river, away from the immediate influence of the plant, was sampled during 1975 to evaluate the use of the intake station as a control to compare with the discharge. The phytoplankton parameters were measured initially and 24 hours after collection. The 24-hour observations provide information on latent effects of entrainment on recovery of the community which may not be exhibited immediately following entrainment. The initial and 24-hour measurements provide independent evaluations of entrainment effects.

The sampling schedule was designed to account for seasonal variation in species composition, ambient physicochemical conditions, and plant thermal discharge. Surveys were conducted in June, August, and November of 1975 and monthly from April through November 1976.

Duplicate, whole-water samples were taken at each sampling station on each sampling date (four days per season in 1975 and twice monthly in 1976). Equal volumes of mid-depth and surface samples were composited at the river control station. Water was taken from just below the surface and near the bottom at the intake and from the discharge standpipe at the discharge

TABLE 4-1 PHYTOPLANKTON PARAMETER STUDIES AT THE BOWLINE POINT PLANT, 1975 AND 1976

	1975		1976	
	Initial	24-Hour	Initial	24-Hour
C-14 Productivity	X	X	X	X
Density	X	X	X	
ATP			X	X
Chlorophyll _a_	X	X	X	X
Fluorescence			X	X

station. Temperature, tidal stage, and time of collection were recorded for each sample. Twelve liters of water from each station was stored in a plastic bucket with an airtight lid and then processed at the onsite laboratory. Initial processing (discussed later for each major parameter) was performed within 1 to 6 hours after collection. When initial processing was completed, the buckets were resealed and held in black incubation troughs supplied with flow-through ambient water for determination of latent effects. Latent effects were observed from 24 to 30 hours after collection, depending on the technique or parameter being evaluated. The incubation troughs were exposed to direct sunlight and contained two recording pyrheliometers to measure light intensity. Water was pumped to each trough from near the plant intake. Temperatures within the troughs remained within 0.5 C of the ambient intake water.

4.2.1 Primary Productivity

The rate at which organic material is synthesized from inorganic carbon (primary productivity) was measured by determining the rate of uptake of the radioisotope, carbon 14. From each composite water sample, 100 ml of water were placed in each of four BOD bottles. Each bottle had 0.5 ml of $NaH^{14}CO_3$ (activity 1 µCi/ml) added. Two of the four bottles were wrapped with aluminum foil to block out all light and the other two unwrapped bottles were exposed to the light. The bottles were randomly inserted in the flow-through troughs and incubated at ambient (intake) water temperature for a minimum of four hours. Temperature, pH, salinity, and inorganic carbon (available for algae productivity) were measured at the beginning of incubation.

Following incubation, the contents of each light bottle were filtered through 0.45-µm filters and placed in labeled liquid-scintillation vials filled with "cocktail fluor." After filtration of the light bottles, the procedure was repeated for the dark bottles. Two liquid scintillation vials (blanks) were inoculated with 0.1 ml of the radioactive carbon solution simultaneous with the samples. These two vials served as the measure of the concentration (activity) of the radioactive carbon material.

Samples were counted in a Packard Tricarb, Model No. 3375 liquid scintillation counter. The observed counts per minute were corrected for internal count absorption (quenching). These corrected counts were converted to production rate in milligrams of carbon per liter per hour (mg C/ℓ/hr) the equation:

$$\text{Rate} = \frac{\left(\frac{DPM_1 - DPM_d}{DPM_i}\right)(C)\left(\frac{V_i}{V_f}\ (ID)\right)}{\text{incubation time (hours)}}$$

where

DPM_1 = counts per minute; light bottle
DPM_d = counts per minute; dark bottle
DPM_i = counts per minute; inoculated
C = carbon available as ppm inorganic carbon
V_i = volume inoculated in ml
V_f = volume filtered in ml
ID = isotope discrimination factor (1.05).

4.2.2 Chlorophyll a Determination

Because chlorophyll a is the primary pigment involved in the photosynthetic process, determination of its concentration provides a measure of photosynthetic rate and biomass. From each sample, 10 ml of water were filtered through a Reeves Angel 984H filter pad. The filter pad was then macerated in 90 percent acetone for approximately one minute with a motorized tissue grinder. This suspension was filtered a second time and the extract was adjusted to a final volume of 10 ml with 90 percent acetone.

The fluorescence of the acetone extracts was measured and recorded for three colored glass filter combinations in a Turner Model 111 fluorometer. The acetone extracts were then acidified and after a 2- to 3-minute delay, were reread in the fluorometer for the three filter combinations. The concentration of chlorophyll a was calculated by the method of Loftus and Carpenter (1971) and Moreth and Yentsch (1970).

The fluorescence of a standard solution was periodically read as a calibration check on the instrument. Ethidium bromide solutions (2 mg/ℓ in distilled water) were used as the standard.

4.2.3 Adenosine Triphosphate (ATP)

The measurement of ATP is an indication of viable biomass in that ATP is present in living cells and is not found in dead cells or associated with detrital material (Holm-Hansen and Booth 1966). From each mixed sample, 1 liter of water was filtered through a 363-μm mesh net to remove large zooplankton. Four 200-ml aliquots of the filtrate were passed throughglass-fiber filters at a vacuum pressure of less than 5 psi. The filters were immersed into a vial of boiling TRIS (115 C) for 5 minutes to inactivate enzymes and complete ATP extraction. The vial was then capped and frozen at -20 C until laboratory analysis. The laboratory process involved the firefly luciferase assay as described by Chappelle et al. (1975). This procedure is done by injecting a volume of the sample into a luciferase preparation, and reading the quanta of light emitted. The instrument used to measure light emission was a Lab-Line Model 9140 ATP photometer.

4.2.4 Fluorescence Microscopy

Chlorophyll fluoresces when exposed to ultraviolet light and the intensity of the fluorescence can be used as a measure of the effect of sublethal stress (Lanza and Cairns 1972) on the relative health of the population. An aliquot of whole water was filtered through a gridded filter at less than 1 psi. The filter was mounted in water and microscopically examined. The organisms were separated into: diatoms, green algae, blue-green algae, flagellates, and others; and their live physiological condition (based on the coloration of the autofluorescence of chlorophyll) was recorded. Bright red autofluorescence denoted a healthy condition; orange-pink, a semi-healthy condition; and pale yellow-green, an unhealthy condition. Dead organisms do not fluoresce and thus were not detected by this method. The percent of healthy phytoplankton surviving entrainment was estimated by

$$P_e = 100 \times \frac{P_{se}}{P_s}$$

where

P_e = proportion healthy following entrainment
P_{se} = proportion healthy following entrainment and sampling (discharge)
P_s = proportion healthy following sampling (intake)

This calculation corrects the proportion healthy at the discharge for sublethal damage incurred during sampling as reflected by the intake samples.

4.2.5 Photoplankton Density

From each sample, approximately 900 ml of whole water were preserved with 10 ml of Lugol's solution. From each preserved sample an aliquot was drawn through a 1.2-µm gridded filter with a vacuum pump operating at a suction level of 7 psi or less. The filters were allowed to air dry at room temperature before they were cleared and permanently mounted on microscope slides.

Approximately 300 algae were identified and counted per sample. Each cell was counted as a unit for diatoms and other single cell forms; colonial and filamentous algae were counted as a single unit per colony or filament. Only those cells, colonies, or filaments appearing to have normal shaped and located chromatophores (or coloration in the case of blue-green algae) were counted.

4.2.6 Analytical Procedures

Primary productivity, chlorophyll a concentration, ATP, fluorescence, and density data were statistically examined using analysis of variance for replicated data. Sampling days were nested by month. Program P2V of BMDP (Dixon and Brown 1977) which grouped data by month and sampling location (intake or discharge) was used to evaluate seasonal and station differences for significant entrainment effects.

4.3 RESULTS

The phytoplankton community sampled was similar between the intake and discharge stations for each season sampled (Appendix B). Diatom species dominated the community in both 1975 and 1976 with green, blue-green, and flagellate species collected in much lower abundance (EA 1976 and 1977b) except in July and September of 1976.

Generally 2 to 5 species accounted for more than 50 percent of the organisms collected during each season. The species diversity was similar in both years with 140 and 123 species collected in 1975 and 1976, respectively (EA 1976 and 1977b).

No significant ($p > 0.05$) differences in phytoplankton densities were found between the river and the Bowline plant intake during 1975 (EA 1976). This lack of difference between the river and intake and the similarity of the seasonal trends in the community support the use of intake samples as controls for the evaluation of entrainment effects. Consequently, samples were collected only at the intake and discharge stations during 1976.

Seasonal changes in the phytoplankton community were consistently the most significant ($p<0.001$) factor contributing to the variability observed for all of the productivity and condition parameters examined (Table 4-2). The sampling location was a significant source of variability in initial samples for density, chlorophyll a, ATP, and fluorescence but not for primary productivity. Although the significance of location increased for primary productivity, it decreased for the other four parameters during the 24 hours following entrainment.

The location effect identified by analysis of variance (Table 4-2) was generally observed as a trend toward reduced productivity, density, and condition at the discharge station (Table 4-3, Figures 4-1 to 4-5). Primary productivity (Figure 4-1) exhibited an initial annual average reduction of 23 and 20 percent at the discharge in 1975 and 1976, respectively; densities for the same periods were reduced 27 and 23 percent (Figure 4-2). Chlorophyll a, ATP concentration, and fluorescence (percent healthy) exhibited reductions of 27, 21, and 7 percent during the individual years when these data were recorded (Figures 4-3 to 4-5).

Although measurements made 24 hours following entrainment showed reductions at the discharge, the reductions were considerably smaller than observed initially (Table 4-3). Primary productivity was only 6 and 16 percent lower at the discharge 24 hours after entrainment in 1975 and 1976, respectively. The associated density reduction was 9 percent in 1975; density was not measured at 24 hours in 1975. Discharge reductions at 24 hours in ATP, chlorophyll a, and fluorescence were 12, 22, and 2 percent, respectively.

Autofluorescence in discharge samples corrected for condition of controls (intake samples) indicates that 93 percent of the surviving phytoplankton are in a healthy condition immediately following entrainment. At 24 hours following entrainment the number of healthy organisms had increased to 98 percent.

4.4 DISCUSSION

The phytoplankton community at the Bowline Point plant exhibits strong seasonal fluctuations in condition and primary productive capacity consistent with those patterns expected in a temperate zone estuary. Primary productivity (mg of inorganic carbon fixed ℓ/hr), concentrations of chlorophyll a and cellular ATP, phytoplankton density, and healthy proportion generally increase from a minimum in the spring to early summer peaks and then decrease to low levels in the late fall. The parallel intake and discharge curves (Figures

TABLE 4-2 SUMMARY OF ANALYSIS OF VARIANCE F VALUES FOR PHYTOPLANKTON ENTRAINMENT STUDIES CONDUCTED AT THE BOWLINE POINT PLANT, 1975 AND 1976

Year	Observation Interval	Parameter	F Location	 Month
1975	Initial	Primary productivity	2.22	22.76**
		Chlorophyll a	26.37**	133.73**
		Density	22.34**	39.08**
	24-hour	Primary productivity	6.26*	58.46**
		Chlorophyll a	0.98	20.18**
		Density	5.84*	76.23**
1976	Initial	Primary productivity	1.80	16.76**
		ATP	35.07**	52.62**
		Density	37.88**	75.48**
		Fluorescence	7.06*	33.88**
	24-hour	Primary productivity	21.63**	32.76**
		ATP	1.73	22.81**
		Density	Not measured	
		Fluorescence	0.35	21.10**

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*$p < 0.05$
**$p < 0.001$

TABLE 4-3 PERCENT DECREASE IN PHYTOPLANKTON PARAMETERS BETWEEN INTAKE AND DISCHARGE STATIONS AT THE BOWLINE POINT PLANT, 1975 AND 1976

Parameter	Percentage Change			
	1975		1976	
	Initial	24-Hour	Initial	24-Hour
Primary productivity	23.0	6.1	19.7	15.5
Density	27.0	8.5	23.2	--
Chlorophyll a	26.6	22.0	--	--
ATP	--	--	20.8	11.9
Fluorescence	--	--	6.7	1.8

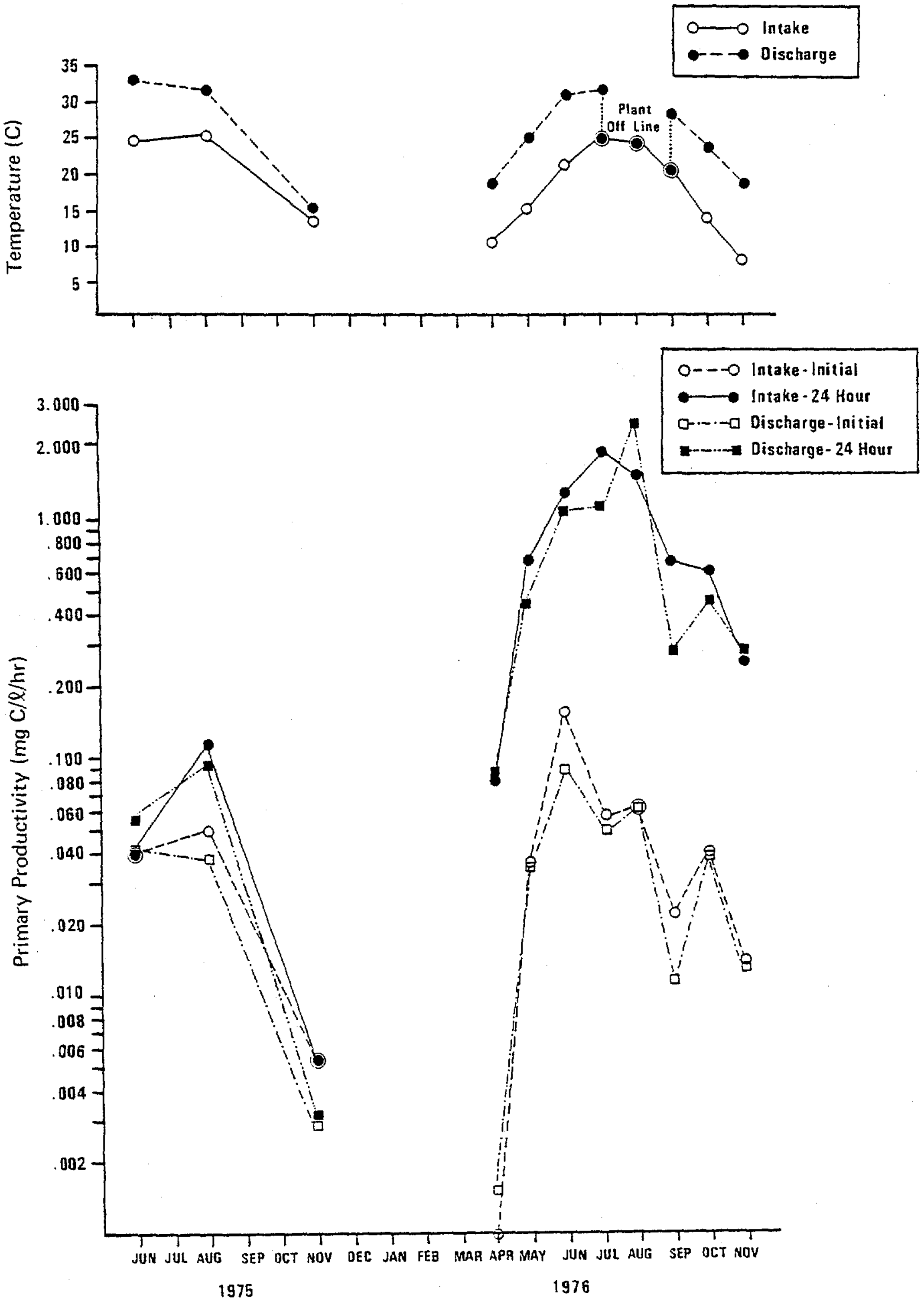

Figure 4-1. Primary productivity (mg C/ℓ/hr) measured at the intake and discharge, initially and 24-hours following entrainment at the Bowline Point plant, 1975–1976.

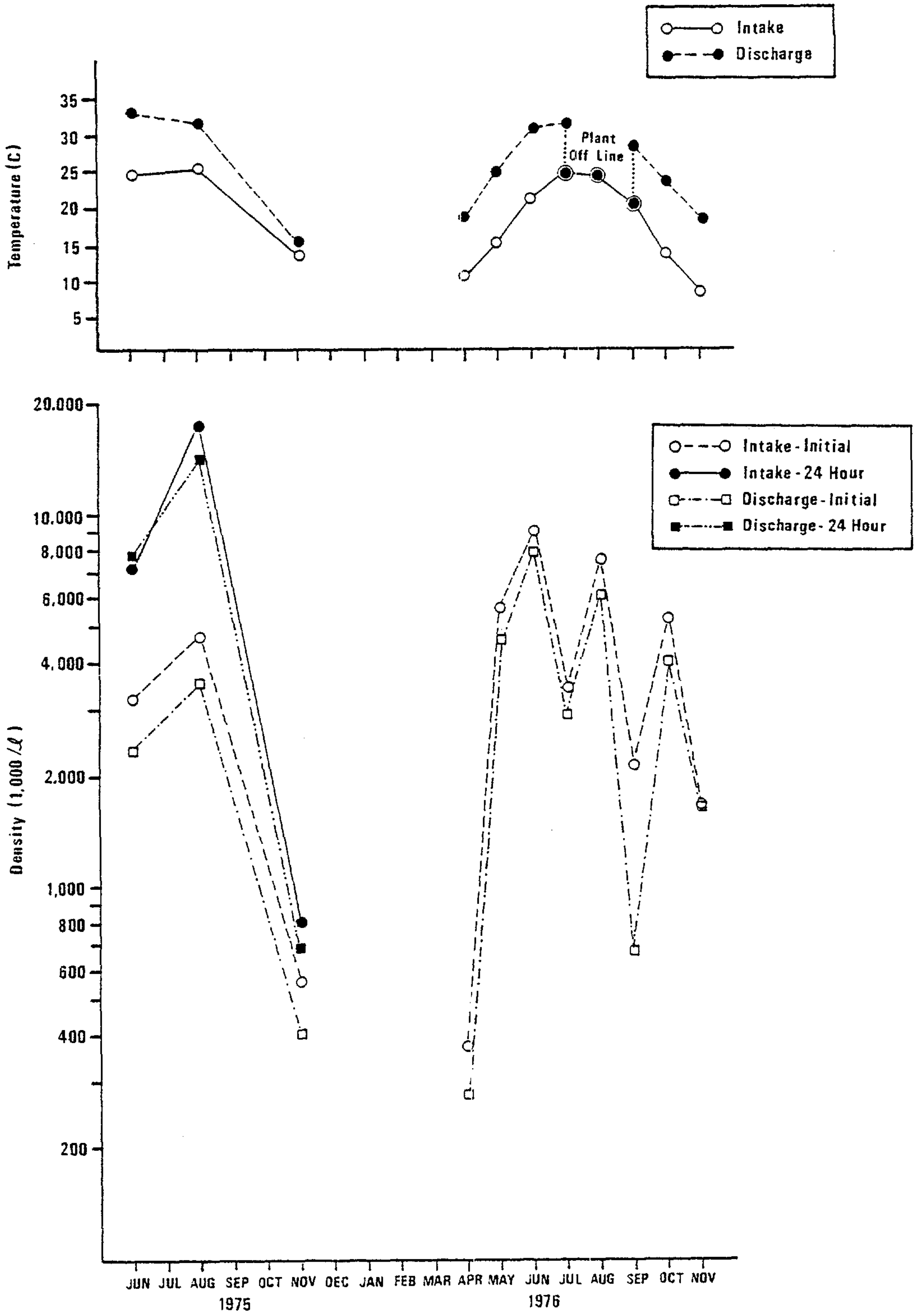

Figure 4-2. Density of phytoplankton measured at the intake and discharge, initially and 24-hours following entrainment at the Bowline Point plant, 1975—1976.

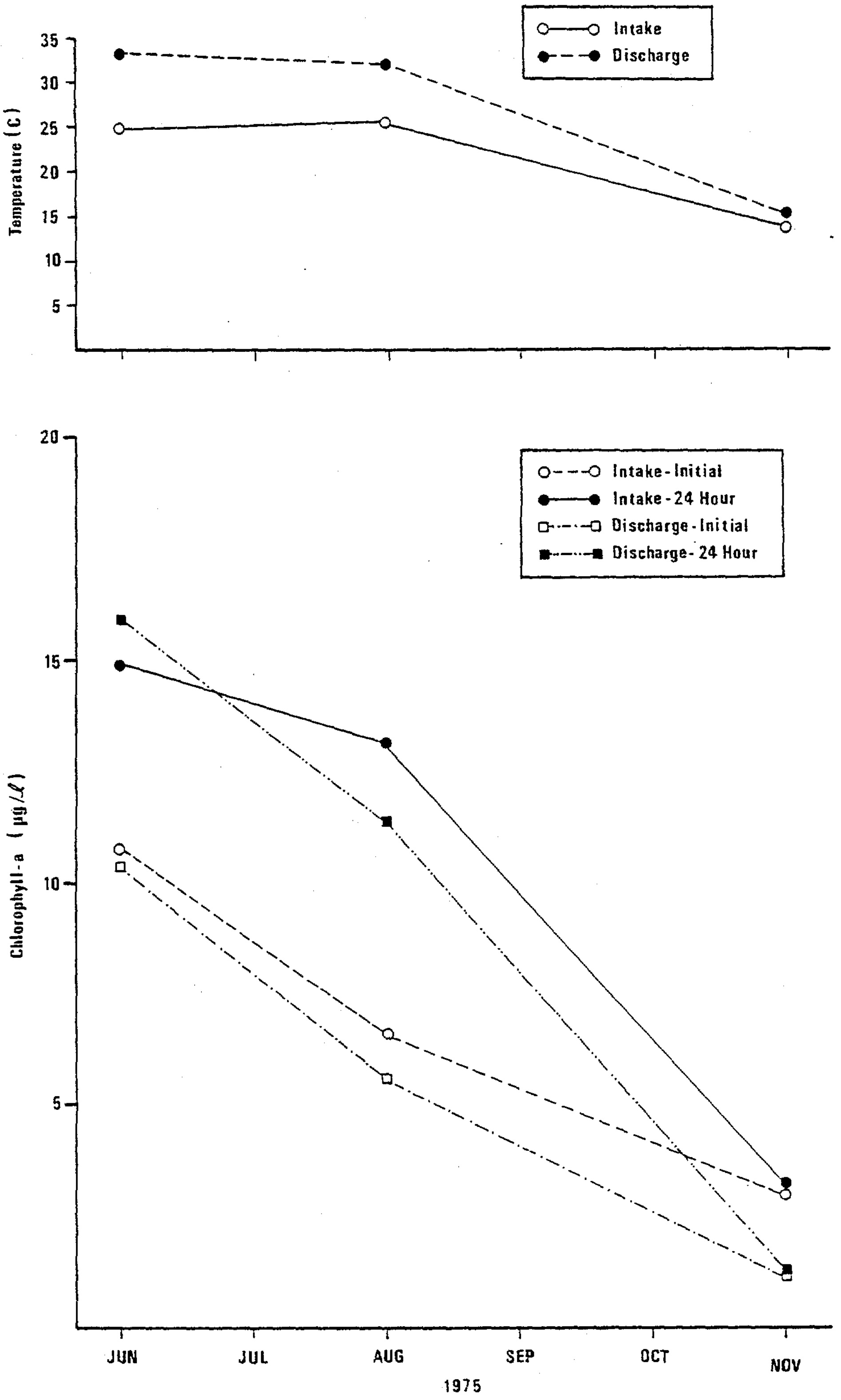

Figure 4-3. Chlorophyll a (µg/ℓ) measured at the intake and discharge, initially and 24-hours following entrainment at the Bowline Point plant, 1975.

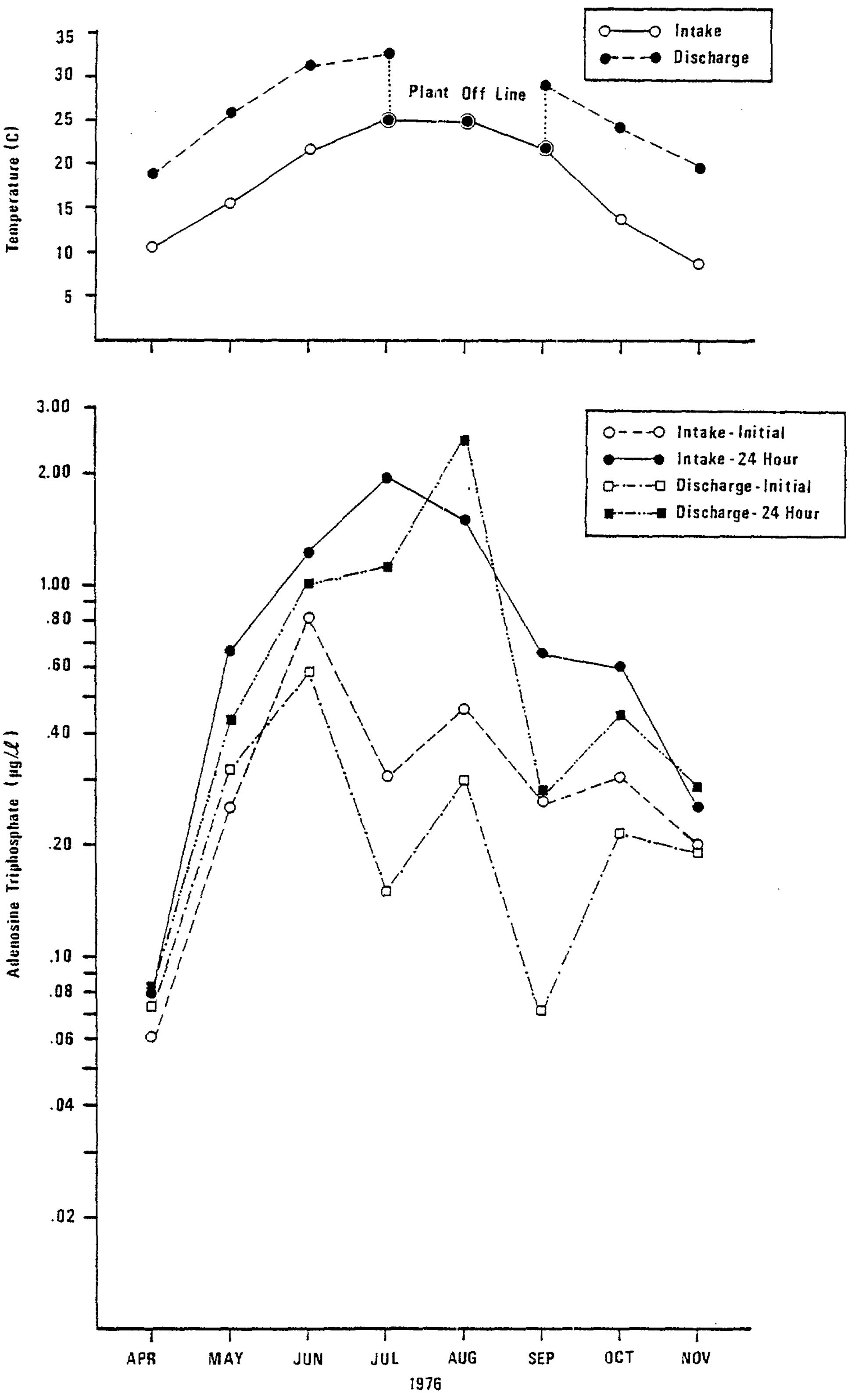

Figure 4-4. Adenosine triphosphate (µg/ℓ) measured at the intake and discharge, initially and 24-hours following entrainment at the Bowline Point plant, 1976.

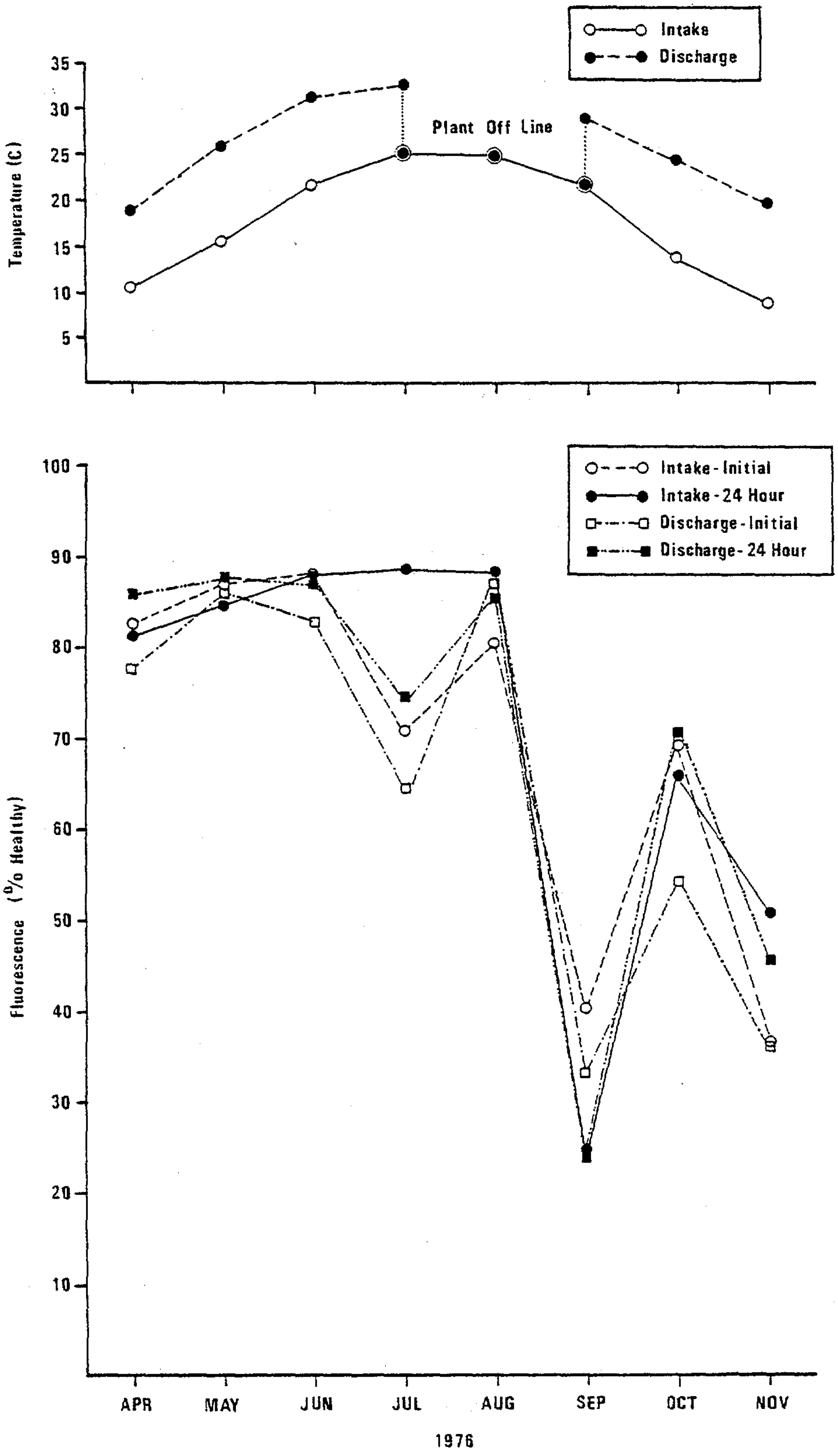

Figure 4-5. Health of the phytoplankton community as measured by fluorescence, at the intake and discharge of the Bowline Point plant, 1976.

4-1 to 4-5) for all five of these parameters indicate that entrainment does not tend to alter these natural seasonal trends.

The observed trend toward lower primary productivity, density, ATP, and chlorophyll a at the discharge indicates that entrainment causes an initial 20-27 percent reduction in the overall productive capacity of the phytoplankton community. The community exhibits relatively rapid recovery from entrainment with the effects on primary productivity, density, and ATP being reduced from 20 to 27 percent initially to 6 to 16 percent at 24 hours. The magnitude of these reductions was not associated with discharge temperatures or delta-T which did not exceed 33.4 C and 12.6 C, respectively, during this study. It may therefore be concluded that the observed reductions are primarily a result of the mechanical stresses associated with entrainment and that no additional thermal effects may be expected at the Bowline Point plant when discharge temperatures are below 33.5 C. This conclusion is consistent with the results of thermal tolerance studies conducted by New York University (NYU 1974) which predicted no thermal mortality below 38 C.

The portion of the phytoplankton community which initially survives entrainment exhibits minimal physical damage as a result of the experience. Fluorescence microscopy indicates that 93 percent of the live organisms are healthy following entrainment. Since a high percentage of entrained phytoplankton surviving entrainment are healthy it is unlikely that any latent effects of entrainment would be observed. In fact, the healthy condition and short phytoplankton generation times promote rapid recovery reflected by the sharp increase in ATP, photosynthetic pigments, and plankton density observed within 24 hours of entrainment.

In summary, entrainment of phytoplankton through the Bowline Point plant may result in a 20-27 percent initial reduction in the primary productive capacity of the entrained population when discharge temperatures are below 33.5 C. No relationship between reduced productivity and discharge temperatures was observed up to 33.4 C (the maximum temperature recorded during these studies). Consequently, no thermal effects are expected as a result of normal plant operation when discharge temperatures remain below 33.5 C. Much of the reduction in productivity due to mechanical stress is mitigated by the rapid recovery of the population and increases in density associated with the short generation time of most phytoplankton species.

5. INVERTEBRATE ZOOPLANKTON ENTRAINMENT

5.1 INTRODUCTION

Invertebrate zooplankton fill an important link in the transfer of energy and organic material through the food web. Some of these taxa feed on both algae and/or detrital particles and subsequently provide food for larger invertebrate and vertebrate carnivores. The critical role of invertebrate zooplankton as a food source for higher trophic levels has resulted in this evaluation of zooplankton survival at the Bowline Point plant. The initial survival of micro- and macrozooplankton and latent effects of entrainment were examined during 1975, 1976, and 1978 (macrozooplankton only). The differences in size range (less than or greater than 1 mm) and abundance required slightly different procedures for studying survival of micro- and macrozooplankton. Microplankton studies emphasized selected abundant copepods, rotifers, cladocerans, and molluscan larvae while macrozooplankton studies focused on the most abundant taxa (Gammarus spp., Monoculodes edwardsi, Neomysis americana, and Chaoborus punctipennis).

5.2 MICROZOOPLANKTON

5.2.1 Methods and Materials

5.2.1.1 Field Methodology

To determine the survival of microzooplankton in the once-through cooling system at the Bowline Point plant, samples were collected from the intake (control) and discharge. Samples were collected for survival determinations using a centrifugal 10-cm pump and a 76-μm mesh plankton net to filter water. During 1975 water was pumped into a larval table (Section 6.3) which was then drained through the plankton net. However, in 1976 water was pumped directly into the net suspended in a tank filled with water. Water temperature was recorded on each sampling day. In 1975, samples were collected from 2 to 5 successive days during summer (July-August), fall (September-October), and winter (December). During 1976, samples were collected twice monthly from March through December and data were pooled seasonally based on ambient river and discharge temperatures:

Early spring	8 March - 26 April
Late spring	10 May - 7 June
Summer	21 June - 13 September
Early fall	27 September - 4 October
Late fall	25 October - 1 November
Winter	15 November - 6 December

5.2.1.2 Sample Processing

After washing the nets the contents of the codend were transferred into a jar and the volume was adjusted to 800 ml. From each thoroughly mixed sample 21 aliquots of 5 ml were removed and placed in covered culture dishes held at ambient intake temperatures. Three aliquots were examined initially and at each latent effects observation period (24, 48, 72, and 96 hours following collection). Because deterioration and decay of dead organisms in the subsamples during extended holding periods prevented positive identification and, consequently, resulted in inaccurate survival estimates, the 72- and 96-hour data were not used for analysis. At the initial and latent effects observations the 3 aliquots were examined using 25X and 40X magnification to identify and enumerate all dead organisms. The criterion for death was failure of an organism to respond to a gentle probing stimulus. After the dead count was completed each aliquot was preserved in 5 percent formalin and total population counts were made at a later date.

5.2.1.3 Analytical Methodology

Analysis of entrainment survival data involved the determination of initial and 48-hour survival at the intake and discharge. This was accomplished by dividing the number of live organisms by the total number collected (live + dead). For this calculation all three aliquots from a sample and observation period were pooled.

Comparisons of intake and discharge survival were made by means of Fisher's exact probability test (Sokal and Rohlf 1969) for all worse-case frequency distributions:

	Live	Dead	
Discharge	a	b	a + b
Intake	c	d	c + d
	a + c	b + d	n

$$p = \frac{(a+b)!\ (c+d)!\ (a+c)!\ (b+d)!}{a!\ b!\ c!\ d!\ n!}$$

The null hypothesis ($p_i \ngtr p_d$) for a one-tailed test is rejected if the sum of p for all worse cases is less than or equal to 0.05 (i.e., it can be concluded that intake survival is significantly greater than discharge survival).

The data were partitioned by discharge temperatures and corrected for sampling related mortality to evaluate thermal and mechanical effects of entrainment. EA (1977c) reviewed several sources of thermal tolerance data for the major microzooplankton taxa entrained and concluded that 35 C was the approximate upper lethal thermal threshold. Since no thermal mortality would be expected below this threshold all data collected at discharge temperatures below 35 C were pooled to estimate mechanical mortality. Above 35 C survival data reflect the combined effects of the thermal and mechanical stresses of entrainment. To factor out sampling-induced mortality (intake samples), the discharge survival was corrected for intake mortality as follows:

$$S_e = \frac{P_e P_s}{P_s}$$

where

S_e = proportion surviving entrainment
P_eP_s = proportion surviving entrainment and sampling (discharge survival)
P_s = proportion surviving sampling alone (intake survival).

5.2.2 Results

Survival of microzooplankton entrained at the Bowline Point plant was highly variable within and between years at the intake and discharge sampling stations. During 1976 initial survival of total microzooplankton at both stations was generally higher than observed during the same seasons in 1975 (Appendixes C-1 to C-4):

	Percent Survival	
Year	Intake	Discharge
1975	63.2-76.3	54.3-63.7
1976	59.7-96.9	49.0-93.0

The patterns observed for total microzooplankton generally reflected the seasonal changes observed for copepod nauplii, the most abundant taxa (Figure 5-1, Table 5-1). Fluctuations in discharge survival generally paralleled survival at the intake. During 1976 survival at both stations was lowest in the spring and late fall (less than 70 percent) and highest in the summer and early fall (greater than 80 percent). Comparison of intake and discharge survival demonstrated significant (= 0.05) reductions at the discharge for individual taxa and dates in 21 of 57 and 9 of 14 comparisons for 1976 and 1975, respectively. No consistent relationship was observed between these reductions and plant operating mode (Figure 5-1). Forty-eight hours following entrainment 15 of 54 and 5 of 11 comparisons exhibited significant reductions in 1976 and 1975, respectively.

Survival of mechanical stresses of entrainment was 92.6 percent initially for total microzooplankton and ranged from 58.2 to 100 percent for the major individual taxa (Table 5-2) during 1976. Mechanical effects were greater in 1975 when survival for total microzooplankton was 84.1 percent and ranged from 49.3 to 100 percent for individual taxa. Because significant (= 0.05) differences between the intake survivals calculated for the two years indicate significantly different sampling effects the data for the two years were not pooled. In most cases (9 of 12) entrainment survival 48 hours after collection was higher than initial survival during 1976; during 1975, 5 of 7 taxa exhibited higher survival at 48 hours, following mechanical entrainment stress.

Entrainment survival at discharge temperatures above the lethal threshold (35 C) was generally lower than for mechanically stressed organisms immediately following collection. Survival for total microzooplankton collected at 35 C or higher temperatures was 90.1 and 74.4 during 1976 and 1975, respectively. The range of survival for individual taxa was 91.0 to 72.7 percent and 73.8 to 43.5 percent during 1976 and 1975. Forty-eight hours following entrainment, survival was often higher than initial survival (5 of 9 cases). On the only date in 1976 that discharge temperatures reached 35 C (23 August), survival decreased to a summer minimum for total microzooplankton and copepod

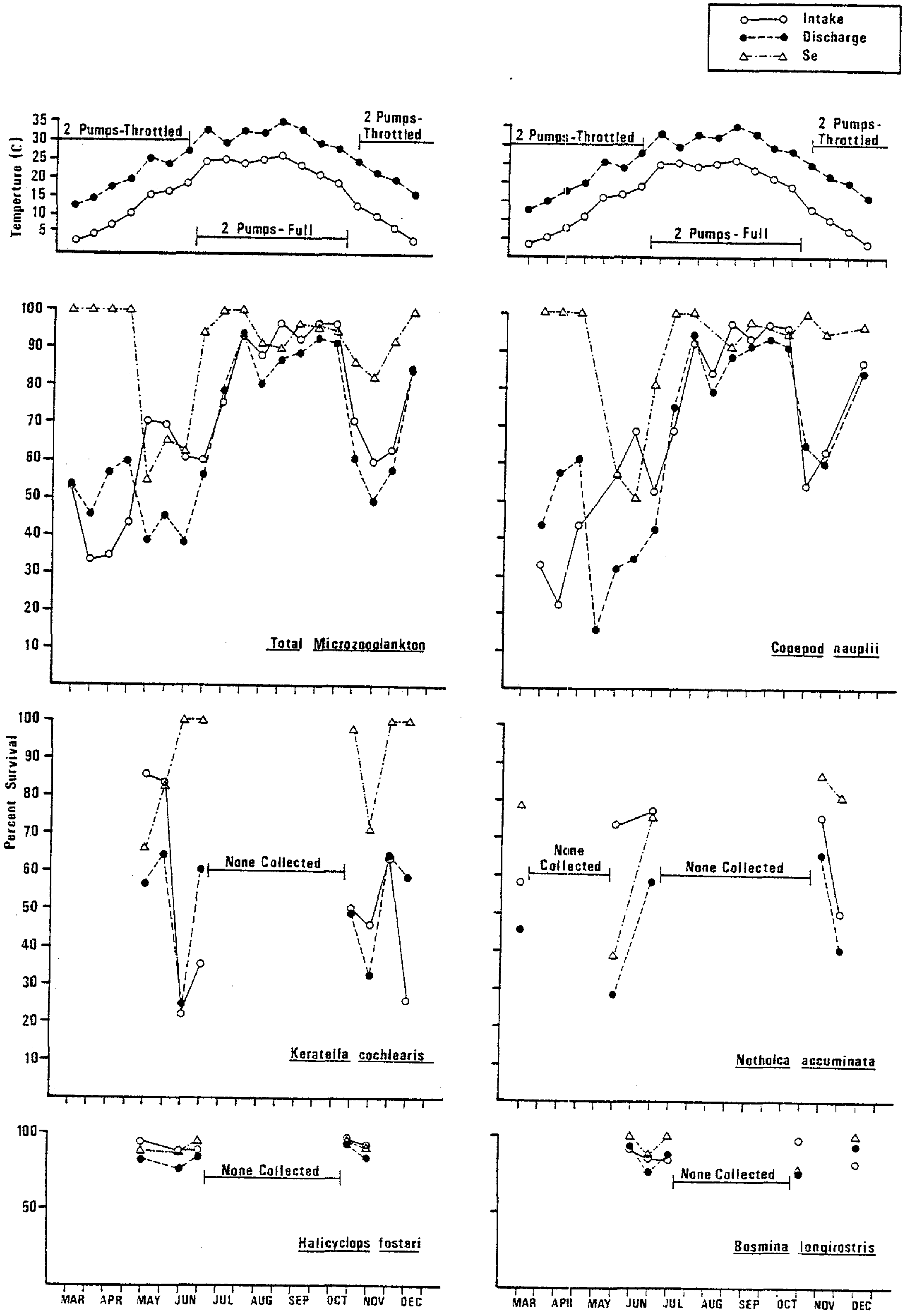

Figure 5-1. Seasonal variation of percent survival for the major microzooplankton taxa entrained at the Bowline Point plant during 1976.

TABLE 5-1 SEASONAL VARIATION IN TOTAL MICROZOOPLANKTON AND COPEPOD NAUPLII INITIAL SURVIVAL AT THE BOWLINE POINT PLANT INTAKE AND DISCHARGE, 1976

		Average Temp. (C)		Percent Survival		
Taxa	Season	I[a]	D	I	D	S_e %[b]
Total microzooplankton	Early spring	6.6	15.8	40.6 (1,690)(c)	57.0 (967)	100.0
	Late spring	16.9	25.6	67.6 (6,780)	42.1 (3,121)	62.3
	Summer	24.6	32.4	84.5 (12,738)	80.5 (11,478)	95.3
	Early fall	19.9	28.6	96.1 (1,269)	92.7 (1,028)	96.5
	Late fall	11.4	23.2	63.9 (1,440)	56.2 (1,821)	87.9
	Winter	5.4	18.0	79.6 (1,388)	79.9 (1,153)	100.0
Copepod nauplii	Early spring	6.6	15.8	39.0 (1,369)	57.3 (785)	100.0
	Late spring	16.9	25.6	60.7 (2,407)	29.4 (966)	48.4
	Summer	24.6	32.4	88.8 (8,516)	84.4 (7,970)	95.0
	Early fall	19.9	28.6	97.1 (1,107)	92.9 (855)	95.7
	Late fall	11.4	23.2	60.3 (156)	63.7 (567)	100.0
	Winter	5.4	18.0	87.2 (836)	84.5 (692)	96.9

(a) I = intake; D = discharge.

(b) $S_e = P_{sD}/P_{sI}$ = entrainment survival.

(c) The total number of organisms collected is indicated in parentheses.

TABLE 5-2 ENTRAINMENT SURVIVAL OF MOST ABUNDANT MICROZOOPLANKTON TAXA AT THE BOWLINE POINT PLANT, CALCULATED FOR 1975 AND 1976

Taxa	Discharge Temperature (C)	Entrainment Survival (%) 1975 Initial	1975 48-Hour	1976 Initial	1976 48-Hour
Total microzooplankton	<35	84.1	96.2	92.6	96.7
	35-37	74.4	48.1	90.1	98.1
Copepod nauplii	<35	67.2	47.3	100.0	100.0
	35-37	71.5	44.0	91.0	100.0
Eurytemora affinis	<35	49.3	48.3	74.9	82.1
	35-37	55.9	--	--	--
Acartia tonsa	<35	--	--	93.6	100.0
	35-37	43.5	58.4	78.8	72.6
Halicyclops fosteri	<35	100.0	100.0	89.5	89.9
	35-37	53.4	--	--	--
Bosmina longirostris	<35	100.0	100.0	98.5	93.1
	35-37	59.3	42.6	--	--
Keratella cochlearis	<35	100.0	100.0	90.5	95.2
	35-37	--	--	--	--
Notholca accuminata	<35	90.8	100.0	62.1	82.1
	35-37	--	--	--	--
Kellicottia longispina	<35	--	--	58.2	35.8
	35-37	--	--	--	--
Brachionus calyciflorus	<35	--	--	81.2	100.0
	35-37	--	--	--	--
Pelecypod veliger	<35	--	--	100.0	100.0
	35-37	--	--	72.7	100.0
Gastopod veliger	<35	--	--	100.0	80.9
	35-37	73.8	86.9	--	--

nauplii; however, just before this sampling date conductivity also decreased from approximately 7,000 to 200 μmhos/cm.

5.2.3 Discussion

The seasonal changes in intake, discharge, and adjusted entrainment survival closely parallel the abundance patterns and microzooplankton community succession described by EA (1978a). Although no clear relationship was observed (Figure 5-1) between survival and plant operation in the two-pump full or throttled modes, survival was lowest in the spring (Figure 5-1 and Table 5-1). During the spring, ambient river temperatures fluctuate and increase rapidly. Conductivity is also highly variable, increasing or decreasing several parts per thousand in a few days. The microzooplankton community at this time is characteristically transitional with shifts between freshwater and marine taxa, and overwintering to reproductively-active summer populations. It is possible that during this period microzooplankton may be more sensitive to sampling and entrainment stresses than in other seasons. A population effect is supported by the observed decrease in survival at the intake as well as the discharge. Similar decreases in survival during the fall observed for total microzooplankton, *Keratella cochlearis*, and *Notholca accuminata* may be related to a similar combination of environmental and biological circumstances.

Intake, discharge, and entrainment survival estimates for 1975 were consistently lower than for 1976. This difference is probably related to differences in collecting procedures or the overall condition of the communities sampled in the two years. In 1975 the final step in the collection procedure involved draining a larval table through a net suspended in the air at the table discharge pipe; whereas a plankton net suspended in a barrel of water was the collection device in 1976. The cushioning effect of the water in the barrel may have reduced abrasion, air drying, and other related collection stresses during 1976. Furthermore the thermal exposure in 1976 (25 minutes) was more than double that experienced by microzooplankton in 1976 (10 minutes).

Entrainment of total microzooplankton reduced initial survival 8 to 16 percent when discharge temperatures were below the laboratory-predicted upper-thermal lethal threshold (34-35 C for the most abundant taxa). Decreases in survival following mechanical stress only (discharge temperatures below 35 C) were not related to differences in pumping mode. Although the spring and fall minimum in survival occurred during two-pump throttled operation, winter and early spring survival estimates were nearly 100 percent for the same operating mode. These spring and fall decreases are likely to be related to the seasonal changes in microzooplankton.

At discharge temperatures above the laboratory predicted lethal threshold, initial entrainment survival was reduced 10 to 25 percent for total microzooplankton. The additional 2 to 9 percent reduction observed above 35 C for 1975 and 1976 may be related to thermal stresses. However, during 1976, discharge temperatures reached 35 C on only one sampling date (23 August); whereas the variability of survival estimates for the other individual sampling dates may indicate that the apparent thermal effect is an artifact of experimental variability and limited sampling above 35 C. The sudden decrease in river conductivity (7,000 to 200 μmhos/cm) prior to sampling on 23 August may have stressed the community and confounded any evaluation of thermal entrainment effects for 1976.

The independent estimates of entrainment survival initially and 48 hours following entrainment indicate that recovery of most of the taxa involved is generally fairly rapid. Survival of total microzooplankton at 48 hours, above and below 35 C was 96.7 and 98.1 percent, respectively. The increased survival estimates for many of the individual taxa during the 48 hours following entrainment are the result of high reproductive rates and relatively short generation times of many microzooplankton taxa.

In summary, initial survival of the most abundant microzooplankton taxa entrained at the Bowline Point plant is reduced by less than 16 percent when temperatures are below 35 C. Between 35 and 37 C greater reductions (10 to 25 percent) may occur; however, according to EA (1978a) discharge temperatures in excess of 35 C are unusual at the plant. Although some of the less abundant taxa exhibit decreases of greater magnitude under certain transitory ambient river water quality conditions, initial survival is consistently in excess of 80 percent. Furthermore, the high reproductive rate and short generation times characteristic of most microzooplankton permit the population to rapidly recover following entrainment.

5.3 MACROZOOPLANKTON

5.3.1 Methods and Materials

5.3.1.1 Field Methodology

To determine the involvement and survival of macrozooplankton in the Bowline Point power plant once-through cooling system, samples were collected from both the intake and discharge of the plant. Sample collection usually occurred after sunset, coinciding with the highest densities of organisms. Samples were collected by pumping known volumes of water into larval collection tables at a rate of 500-800 liters/minute. Specimens were collected in conjunction with ichthyoplankton survival samples as described in Section 6.3.2. Water temperature was recorded in 1975, 1976, and 1978; conductivity, pH, and dissolved oxygen were also measured in 1976 and 1978. Samples were collected seasonally in 1975, semimonthly in 1976, on one day in March, April, May, and October, and biweekly from June through September in 1978 (Table 5-3).

5.3.1.2 Sample Processing

Samples were returned to the onsite laboratory for sorting and enumeration. Emphasis was placed on different genera in different collection years. During 1975 and 1976 the total macrozooplankton, _Gammarus daiberi_ (Amphipoda), _Neomysis americana_ (Mysidacea), _Chaoborus punctipennis_ (Insecta, Larvae), and _Monoculodes edwardsi_ (Amphipoda) were emphasized. During 1978, special attention was given to _Gammarus_ spp., _Neomysis americana_, _Chaoborus punctipennis_, and _Crangon septemspinosa_ (Crustacea). The criteria for the evaluation of the physiological condition of the organisms were

Live--Normal behavior unique to the species,

Dead--No vital life signs or response to a stimulus (cessation of pleopod beating indicated death of _Gammarus_ spp.), and

Stunned--Aberrant swimming behavior or unable to swim.

TABLE 5-3 FREQUENCY OF SAMPLING FOR MACROZOOPLANKTON INITIAL (0-HOUR) SURVIVAL AND CIRCULATOR PUMP OPERATION AT THE BOWLINE POINT PLANT, DURING 1975, 1976, AND 1978

Date	Gammarus spp.	Neomysis americana	Chaoborus punctipennis	Monoculodes edwardsi	Crangon septemspinosa	Other Macro.	Circulator Pump Operation
1975							
29 JUL	X	X	X	X		X	2 Pumps - Full
30 JUL	X	X	X	X		X	2 Pumps - Throttled
31 JUL	X	X	X	X	X	X	2 Pumps - Full
4 AUG	X	X	X	X		X	2 Pumps - Full
5 AUG	X	X	X	X		X	2 Pumps - Full
29 SEP	X	X	X	X		X	2 Pumps - Full
30 SEP	X	X	X	X		X	2 Pumps - Full
1 OCT	X		X	X		X	2 Pumps - Full
16 DEC	X	X	X	X		X	2 Pumps - Full
1976							
8 MAR	X			X		X	2 Pumps - Throttled
22 MAR	X			X		X	2 Pumps - Throttled
5 APR	X		X	X		X	2 Pumps - Throttled
26 APR	X		X	X		X	2 Pumps - Throttled
10 MAY	X		X	X		X	2 Pumps - Throttled
24 MAY	X		X	X		X	2 Pumps - Throttled
7 JUN	X		X	X		X	2 Pumps - Throttled
21 JUN	X		X	X		X	2 Pumps - Full
12 JUL	X		X	X		X	2 Pumps - Full
13 JUL	X		X	X		X	2 Pumps - Full
26 JUL	X	X	X	X		X	2 Pumps - Full
9 AUG	X	X	X	X		X	2 Pumps - Full
23 AUG	X	X	X	X		X	2 Pumps - Full
13 SEP	X	X	X	X		X	2 Pumps - Full
27 SEP	X	X	X	X		X	2 Pumps - Full
4 OCT	X	X	X	X	X	X	2 Pumps - Full
25 OCT	X	X	X	X	X	X	2 Pumps - Throttled

TABLE 5-3 (CONT.)

Date	Gammarus spp.	Neomysis americana	Chaoborus punctipennis	Monoculodes edwardsi	Crangon septemspinosa	Other Macro.	Circulator Pump Operation
1975							
1 NOV	X		X	X		X	2 Pumps - Throttled
15 NOV	X		X	X		X	2 Pumps - Throttled
6 DEC	X	X		X		X	2 Pumps - Throttled
1978							
20 MAR	X	X					2 Pumps - Throttled
10 APR	X		X				2 Pumps - Throttled
22 MAY	X		X				2 Pumps - Full
12 JUN	X		X				2 Pumps - Full
26 JUN	X	X	X				2 Pumps - Full
5 JUL	X	X	X				2 Pumps - Full
18 JUL	X	X	X		X		2 Pumps - Full
14 AUG	X	X			X		2 Pumps - Full
28 AUG	X	X	X		X		2 Pumps - Full
11 SEP	X	X			X		2 Pumps - Full
25 SEP	X	X			X		2 Pumps - Full
16 OCT	X	X			X		2 Pumps - Full

The live and stunned organisms generally were removed from the sample for incubation within 1.5 hours of collection. Dead organisms were enumerated, removed, and preserved in 5 percent formalin for identification at a later time. The remainder of the sample was preserved in formalin (5 percent in 1975 and 1976 and 10 percent in 1978) for sorting, enumeration, and species identification.

Special incubation methods were followed for macrozooplankton that were to be used in the latent survival studies. When present in sufficient numbers, organisms were held at low densities (Table 5-4) in incubation containers large enough to minimize competition and predation. Incubation containers for Gammarus spp. were provided with Tetra Min fish food and cleaned at 24-hour intervals. Dishes were covered to prevent escape. All dishes were maintained at river ambient temperature.

Latent effects observations were made at approximately 24, 48, 72, and 96 hours during all three study years. In addition, 6-hour and 12-hour observations were made during 1975 and 3, 6, and 12-hour observations occurred during 1978. The number of live, stunned, and dead organisms were counted at each latent effects observation. The dead organisms were removed and preserved in 5 percent formalin. After the 96-hour observation, all remaining organisms were preserved in 5 percent formalin for later identification. The 24-hour observation was chosen in this section as most indicative of power plant latent effects because survival during latent observations was probably confounded by the short, dynamic life cycle of most macrozooplankton. Intake and discharge survival curves level out and become parallel after 24 hours, indicating that most latent effects are probably suppressed by 24 hours.

5.3.1.3 Statistical Methods

The analysis of entrainment survival involved the determination of initial and extended (cultured through 96 hours) survival at the intake and discharge. The initial survival proportion was determined by dividing the number of individuals classifed as live and stunned by the total number of organisms initially collected (live, stunned, and dead). Whereas initial survival estimates were based on all organisms initially collected, extended survival was calculated for organisms initially classified as live or stunned and maintained throughout the 96-hour period followed collection. Extended survival was therefore based on an initial proportion surviving of 1.0. Comparisons of the proportion surviving at intake and discharge stations and cross-year (1975, 1976, and 1978) comparisons were evaluated using Multiway Contingency analysis for tests of independence (Sokal and Rohlf 1969) as:

		1975	1976	1978	Total
Intake	Alive				
	Dead				
Discharge	Alive				
	Dead				
	Total				

TABLE 5-4 SPECIES AND NUMBER OF ORGANISMS INCUBATED FOR LATENT SURVIVAL STUDIES AT THE BOWLINE POINT POWER PLANT, HUDSON RIVER ESTUARY, DURING 1975, 1976, AND 1978

Number of Organisms Per Container	1975(a)	1976(a)	1978
Gammarus spp.(c)	≤6	≤10	≤10
Neomysis americana	10-15	≤10	≤5(b)
Chaoborus punctipennis	≤20	≤15	≤10
Monoculodes edwardsi(c)	10-15	≤10	NS
Crangon septemspinosa	NS	1	1(b)

Note: NS = Not sampled.

(a) All organisms cultured in 11.4-cm culture dishes.
(b) *Neomysis* and *Crangon* were cultured in 800-ml glass jars in 1978.
(c) Gammaridean amphipods were fed Tetra Min fish food and cleaned at 24-hour intervals.

Linear and multiple regression analyses (Steel and Torrie 1960) were performed to determine if any physiochemical variables were related to initial or latent survival.

Entrainment survival was calculated with the equation:

$$S_e\ (\%) = P_D/P_I \times 100$$

where

P_D = proportion surviving sampling and entrainment stress (discharge)
P_I = proportion surviving sampling stress (intake)

Although survival in excess of 100 percent is not biologically realistic, calculated values for entrainment survival (S_e) may exceed 100 percent and are a reflection of the variability of observed survival about the population mean for which S_e is an estimate.

5.3.2 Results and Discussion

5.3.2.1 Total Macrozooplankton

The number of macrozooplankton species collected at the Bowline Point power plant varied among the three collection years (Table 5-5) but the differences were due primarily to changes in the emphasis of the sampling program reflected in the sampling schedule rather than real differences in the macrozooplankton community. During 1975 (EA 1976) and 1976 (EA 1977b) attempts were made to evaluate the entire macrozooplankton community within which 18 (1975) and 19 (1976) categories of organisms were identified (Table 5-5). Sampling in 1975 was designed to evaluate seasonal differences (summer, 29 July - 5 August; fall, 30 September - 1 October; and winter, 16 December). Sampling during 1976 was bimonthly from March through December. Although all individual species were not present in collections during both years, the overall composition of the macrozooplankton community around the Bowline Point power plant remained similar with about the same number of species present and/or generally dominating. Collections during 1978 were designed to evaluate the power plant's impact on four representative important species (RIS) and not the entire macrozooplankton community. The following discussion will emphasize yearly comparisons, latent thermal and conductivity effects, and mechanical effects for these four RIS (*Gammarus*, *Neomysis americana*, *Chaoborus punctipennis*, and *Crangon septemspinosa*) along with *Monoculodes edwardsi* which was quite abundant during 1975 and 1976. The remainder of the species collected during 1975 and 1976 will be addressed, but in less detail.

5.3.2.2 *Gammarus*

Gammarus daiberi composed over 90 percent of the identified *Gammarus* collected during 1975 and 1976 (Appendix D-1 to D-4). During 1978 *Gammarus* were identified only to the generic level. Since only 36 *G. tigrinus* and 3*G. fasciatus* were identified during 1975 and 1976, all the data were pooled to discuss the effects of entrainment on survival of *Gammarus*.

TABLE 5-5 NUMBER OF ORGANISMS OF EACH SPECIES OF MACROZOOPLANKTON COLLECTED AT THE INTAKE AND DISCHARGE SAMPLING STATIONS OF THE BOWLINE POINT PLANT, 1975, 1976, AND 1978

Year	Number of Days Collected	Species	Number Intake	Number Discharge
1978	12	*Gammarus* spp.	7,692	4,563
	9	*Neomysis americana*	5,165	2,237
	7	*Chaoborus punctipennis*	84	65
	6	*Crangon septemspinosa*	10	11
1976	20	*Gammarus daiberi*	2,488	1,333
	6	*Gammarus tigrinus*	17	5
	3	*Gammarus* spp.	5	2
	20	Total *Gammarus*	2,510	1,340
	20	*Monoculodes edwardsi*	450	426
	17	*Chaoborus punctipennis*	684	461
	14	Unidentified *Diptera*	77	189
	9	*Corophium tuberculatum*	70	85
	9	*Chiridotea almyra*	19	11
	8	*Neomysis americana*	286	345
	7	*Leptocheirus plumulosus*	48	8
	3	*Edotea triloba*	1	3
	3	*Palaemonetes* spp.	2	1
	3	*Megalopa*	0	3
	3	*Zoea*	30	64
	2	*Melita nitida*	6	0
	2	*Crangon septemspinosa*	3	0
	2	*Ephemeroptera*	0	8
	1	*Unionicola* spp.	1	0
1975	9	*Gammarus daiberi*	339	156
	7	*Gammarus tigrinus*	10	4
	2	*Gammarus fasciatus*	2	1
	3	*Gammarus* spp.	16	27
	9	Total *Gammarus*	367	188
	9	*Monoculodes edwardsi*	336	276
	9	*Chaoborus punctipennis*	907	567
	9	Unidentified *Diptera*	129	25
	9	*Corophium tuberculatum*	22	71
	8	*Neomysis americana*	46	41
	7	*Leptocheirus plumulosus*	21	11
	6	*Edotea triloba*	62	39
	7	*Melita nitida*	9	6
	3	*Zoea*	128	95
	3	*Cyathura polita*	7	0
	2	*Palaemonetes* spp.	3	0
	1	*Unionicola* spp.	2	1
	1	*Crangon septemspinosa*	0	1

Significant yearly differences exist (G = 89.78 with 2 degrees of freedom) in the survival proportions of Gammarus which indicate that sampling stresses or the overall condition of the population were dissimilar among years. Thus, the data could not be pooled across years to evaluate entrainment effects. The significant three-factor interaction term in the analysis (Appendix Table D-5) reflects the change in the relationship between intake and discharge among years. That is, survival at the discharge was slightly higher than at the intake in 1975 and 1978, but lower than at the intake in 1976 (Appendix Tables D-1 to D-3).

Initial survival of Gammarus ranged from 0.837 (1975) to 0.979 (1976) at the intake and from 0.883 (1975) to 0.951 (1978) at the discharge (Appendix Tables D-1 through D-3) of the Bowline Point power plant. No significant difference (G = 1.34 with 1 degree of freedom) in initial survival was found between the intake and discharge samples. For samples with a minimum of 10 organisms, within-year variation in initial survival was generally less than 40 percent. During 1975, 1976, and 1978 the ranges in initial survival at the intake and discharge were: 0.583-1.000 and 0.714-1.000; 0.773-1.000 and 0.833-1.000; and 0.833-0.994 and 0.784-0.986, respectively.

Significant statistical differences ($\alpha = 0.05$) in extended survival were observed at the intake and discharge for Gammarus (G = 34.20 with 1 degree of freedom). Survival was consistently lower for discharge samples than intake samples across the entire latent effects observation period (Figure 5-2). However, considering the relatively large sample sizes in 1976 and 1978, it is doubtful whether this slight difference is biologically significant. Similar to initial survival, differences among years were reflected by the significant year x survival interaction at 24 hours. Extended survival (24-hour) ranged from: 0.864 (1975) to 0.969 (1976) at the intake and 0.690 (1975) to 0.953 (1978) at the discharge (Appendix Tables D-1 to D-3).

Temperature, although not significant, exhibited a negative correlation with both initial and extended survival (Table D-6). Laboratory studies indicate that no reduction in survival should be expected as a result of thermal exposures below 34 C when ambient water temperature is near 25 C (NYU 1973, 1974; EA 1978b). Discharge water temperatures were never in excess of the median tolerance limit (TL_{50}), 38 C; however, specimens collected between 34 and 36 C exhibited some reduction in entrainment survival (10 to 15 percent) as a result of thermal exposure (Tables D-1 to D-3 and EA 1979a). Initial survival exhibited a weak negative association with conductivity during 1976 and 1978 although 24-hour survival was positively related.

Gammarus initial survival at the discharge station was higher when the two circulating pumps were operating in the full (0.969) vs. throttled (0.901) modes. This mechanical stress was evaluated using the closest possible paired dates (30 and 31 July 1975; 7 and 21 June 1976; 4 and 25 October 1976; and 10 April and 22 May 1978) when the two circulating pumps were operating at full and throttled capacity. This procedure was used to reduce any potential bias which might be introduced by the wide range in ambient river temperatures and seasonal changes in the population. Differences in survival proportions were examined using three-way contingency analysis where the overall test of independence among date pairs (observation), pump operation, and survival was

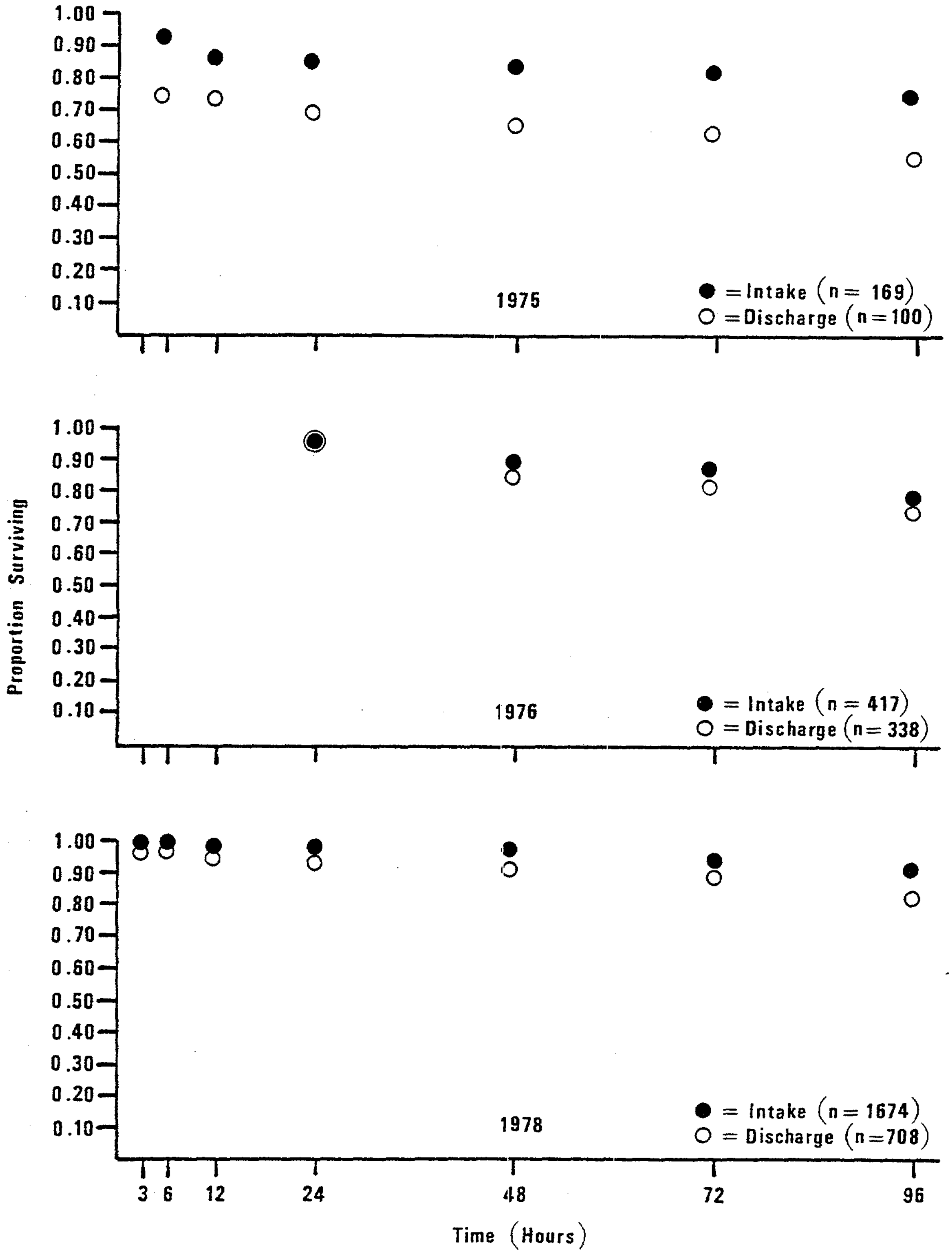

Figure 5-2. Survival curves during latent effects observations for Gammarus collected at the Bowline Point plant, 1975, 1976, and 1978.

highly significant (G = 98.60, 10 degrees of freedom). The pump operation x survival interaction (Table D-7) indicates that the observed difference between the full and throttled modes is significant ($p \leq 0.001$).

Estimates of entrainment survival (Se) for Gammarus were generally higher than 94 percent both initially and at 24 hrs:

	Initial	24-Hour
1975	105.5	84.3
1976	95.3	94.2
1978	100.7	96.0
Average	100.5	91.5

Latent effects of entrainment appeared to result in a decrease of approximately 10 percent in survival at 24 hours.

Estimates of survival which exceed 100 percent are difficult to interpret biologically; however, considering the typically high survival observed at both the intake and discharge, initial survival for the entrained population probably approaches 100 percent. Since individual samples provide independent approximations (Tables D-1 to D-3) of actual entrainment survival, individual estimates which exceed 100 percent survival merely reflect part of the experimental variability inherent in estimates of any population parameter.

Circulating pump operating mode demonstrated no consistent effect on initial and 24-hr survival estimates (Table 5-6). On the other hand, discharge temperatures above 34 C resulted in a reduction in survival compared to temperature below 34 C. This thermal mortality was not apparent initially when survival was approximately 100 percent for both temperature ranges (Table 5-6). At 24-hours survival declined to 81 percent as a result of the increased thermal exposure.

5.3.2.4 Neomysis americana

Yearly differences were found in the initial survival proportions of Neomysis americana collected from the Bowline Point plant and therefore, the three years of data could not be combined. Contingency analysis (Sokal and Rohlf 1969) was used to detect differences in survival among years and between stations for N. americana. The three-way interaction among the three factors may have been a result of progressively improved survival from 1975 to 1976 to 1978 (Tables D-8 to D-10).

Yearly initial survival of N. americana ranged from 0.283 (1975) to 0.846 (1978) at the intake and from 0.706 (1975) to 0.864 (1978) at the discharge (Tables D-4 through D-6). No overall significant difference (Table D-11) in initial survival was found between the intake and discharge station samples. Large variation occurred within years in initial survival with about a 70 percent difference in survival observed during any year (Tables D-8 to D-10).

TABLE 5-6 ENTRAINMENT SURVIVAL (S_e) OF MACROZOOPLANKTON COLLECTED AT THE BOWLINE POINT PLANT AS A FUNCTION OF CIRCULATION PUMP OPERATION AND DISCHARGE TEMPERATURE, 1975, 1976, AND 1978

			Entrainment Survival (%)					
			Two Pumps Full			Two Pumps Throttled		
Taxa	Year	Interval	<30C	30.1-34C	>34C	<30C	30.1-34C	>34C
Gammarus	1975	Initial	*	103.9(a)	123.6	*	--	71.4
		24 hr	*	101.5	67.3	*	--	156.2
	1976	Initial	*	94.4	100.3	*	98.1	--
		24 hr	*	95.2	90.8	*	97.4	--
	1978	Initial	*	99.1	84.8	*	93.8	--
		24 hr	*	96.6	85.8	*	99.9	--
	Averaged	Initial	*	99.1	102.9	*	95.8	--
		24 hr	*	97.8	81.3	*	98.6	--
Neomysis americana	1975	Initial	228.0	--	--	--	--	--
		24 hr	208.4	--	--	--	--	--
	1976	Initial	94.8	83.7	43.2	51.1	--	--
		24 hr	104.5	71.7	22.8	42.2	--	--
	1978	Initial	109.9	89.1	34.6	--	--	--
		24 hr	101.0	84.5	(b)	--	--	--
	Averaged	Initial	144.3	86.4	38.9	51.1	--	--
		24 hr	138.0	78.1	--	--	--	--
Chaoborus punctipennis	1975	Initial	*	115.4	95.3	*	--	100.7
		24 hr	*	117.5	95.3	--	--	99.5
	1976	Initial	*	96.9	92.8	*	98.0	--
		24 hr	*	98.9	*	*	98.0	--

(a) While entrainment survival cannot exceed 100 percent in biological terms, calculated values which exceed 100 reflect the variability within the data base and are therefore presented.
(b) No organisms held for latent effects.

* Data for temperatures ≤30 C are pooled with 30.1-34.0 C for comparisons.
-- Less than 10 organisms at intake and/or discharge.

TABLE 5-6 (CONT.)

			Entrainment Survival (%)					
			Two Pumps Full			Two Pumps Throttled		
Taxa	Year	Interval	<30C	30.1-34C	>34C	<30C	30.1-34C	>34C
Chaoborus punctipennis	1978	Initial	*	109.7	--	*	--	--
		24 hr	*	108.7	--	--	--	--
	Averaged	Initial	*	107.3	94.1	*	--	--
		24 hr	*	108.4	96.7	--	--	--
Monoculodes edwardsi	1975	Initial	*	90.3	118.2	*	--	131.2
	1976	Initial	*	94.9	98.9	*	102.8	--
	Averaged	Initial	*	92.6	108.6	*	--	--

Although significant differences ($\alpha = 0.05$) in extended survival were observed at the intake and discharge for N. americana (Table D-11) no consistent trend was observed among the three years (Figure 5-3). The steady decrease in survival at both stations (intake and discharge) indicates that N. americana are sensitive to holding stress. The slight difference between overall intake (89.3 percent) and discharge (85.1 percent) survival is probably not significant biologically particularly since the marginal association for station and survival is significant (Table D-11, p = 0.026) but the partial association χ^2 is not significant (p = 0.363). Extended survival (24-hour) ranged from 0.583 to 0.885 at the intake and 0.690 to 0.846 at the discharge (Tables D-8 to D-10).

Temperature typically exhibited a negative (and in two cases significant) correlation with both initial and extended survival for N. americana (Table D-12). Entrainment survival was 100 percent at discharge temperatures below 30 C (EA 1979a). At temperatures between 30 and 34 C, a small reduction in entrainment survival was observed, whereas discharge temperatures in excess of 34 C (TL50) caused a sharp decrease in survival (EA 1979a). This sharp decrease in survival above 34 C is consistent with laboratory results reported by NYU (1973) and EA (1978b). This temperature effect was clearly demonstrated on 18 July 1978 when discharge temperatures decreased from 34 to 33 to 32 C on successive samples; survival increased accordingly from 0.713 to 0.785 to 0.871 at the discharge. Although the 1976 data base is more limited and discharge temperatures did not exceed 35 C, the same trend was observed. Entrainment survival (S_e) during 1976 was 33.3, 46.0, 79.1, 93.5, and 96.0 percent at 35, 34, 33, 32, and 29 C, respectively (Table D-9). Regression of survival (S_e) on discharge temperatures for the 1976 and 1978 data above provides an estimate for the median tolerance limit (TL50) of 34.8 C (Figure 5-4) which compares with laboratory estimates of 33.7 C (EA 1978b). Initial and extended survival were not significantly correlated with conductivity.

Differences in mechanical stress between pump modes were not evaluated for Neomysis americana because only four organisms were collected when the pumps were throttled during the four date pairings. However, the close correspondence between the field and laboratory estimates of the TL50 indicate that the overall effects of mechanical stress are minimal and most observed mortality is the result of thermal exposure.

Estimates of entrainment survival (Se) for Neomysis americana exhibited considerable variation among years:

	Initial	24 Hours	Nos. Collected
1975	249.8	182.2	87
1976	85.6	84.8	635
1978	102.1	97.6	7,402
Average	145.8	121.5	

The extremely high estimates for 1975 are a reflection of the small and variable sample sizes and unidentified increase in sampling stress at the intake. Differences between 1976 and 1978 appear to reflect differences in

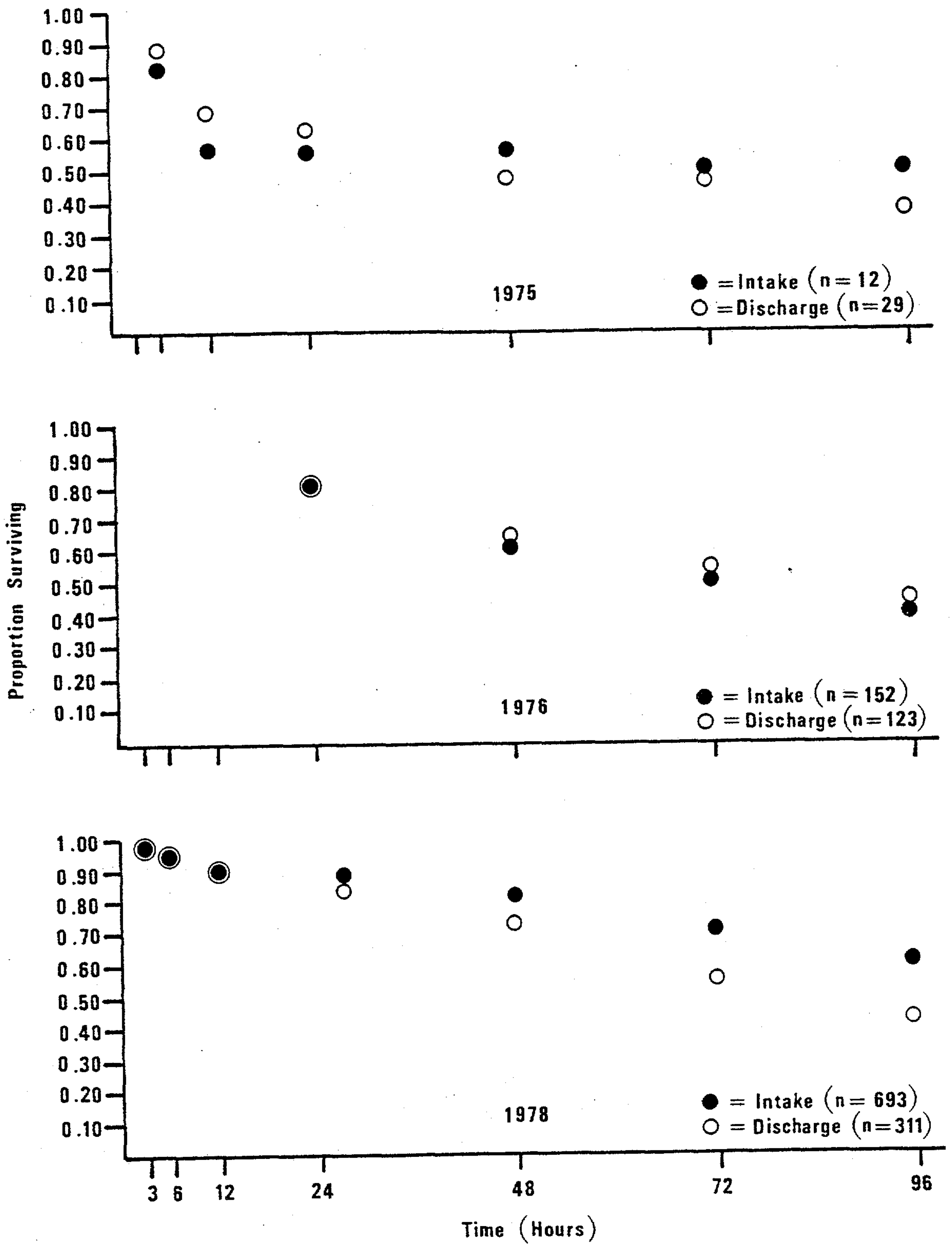

Figure 5-3. Survival curves during latent effects observations for *Neomysis americana* collected at the Bowline Point plant, 1975, 1976, and 1978.

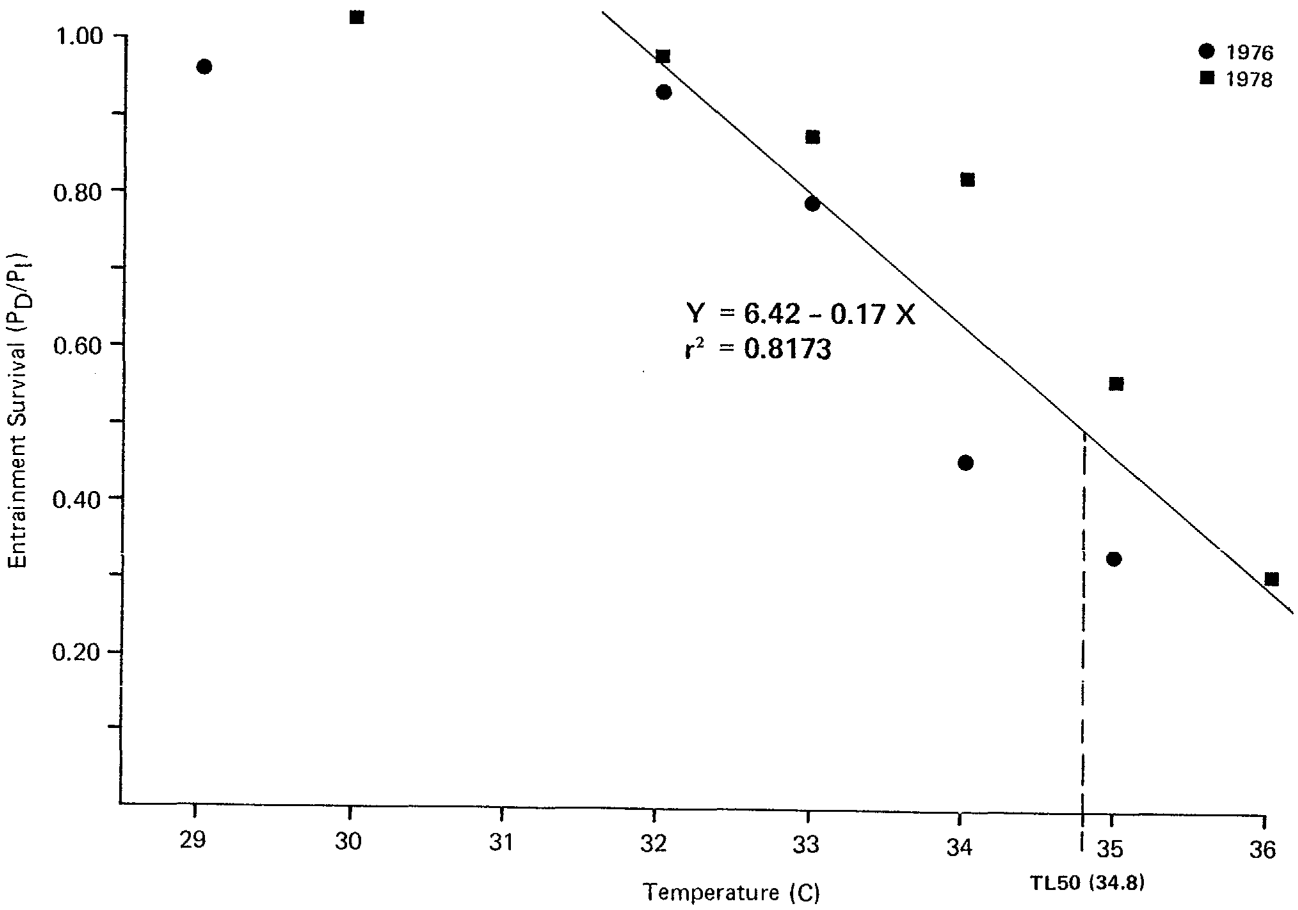

Figure 5-4. Relationship between discharge temperature and survival (S_e) for *Neomysis americana* entrained at the Bowline Point plant, 1976 and 1978.

the relative distribution of organisms collected at various discharge temperatures. Consistent with observations of the extended survival curves, the slight differences between initial and 24-hour Se's in 1976 and 1978 indicate that Neomysis does not exhibit latent mortality as a result of entrainment. A consistent decrease in survival was observed for both initial and 24-hour Se's as temperature increased (Table 5-6).

5.3.2.4 Chaoborus punctipennis

Differences among years were found in the initial survival proportions of Chaoborus punctipennis (Tables D-13 to D-15) collected at the Bowline Point plant, and therefore the data could not be pooled for analyses. Contingency analysis used to detect differences among years, between stations (intake and discharge), and in survival of Chaoborus punctipennis, demonstrated a significant year x survival interaction (Table D-16). The interaction among the three factors was also significant and is partly due to the lower survival at the intake during 1978 (0.857).

Initial survival of Chaoborus punctipennis was consistently high and ranged from 0.857 (1978) to 0.973 (1976) at the intake and 0.919 (1975) to 0.939 (1976) at the discharge sampling stations (Tables D-13 to D-15). No significant difference in initial survival was found between intake and discharge station samples. Chaoborus were collected from April through December and initial survival was generally over 90 percent (Tables D-13 through D-15).

No significant differences (α = 0.05) in extended survival were observed between the intake and discharge for C. punctipennis (Table D-16). Extended survival observations at 24 hours were always within 1 percent of each other across the three years (Tables D-13 through D-15). After the 24-hour observation discharge survival was often higher than the intake survival (Figure 5-5). Two of the three main factors were significant (year x station and year x survival), reflecting annual differences in survival and the relatively low sample size in 1978 (Tables D-13 to D-16).

Conductivity demonstrated a significant negative correlation with survival in two instances during 1976 (Table D-17), as would be expected for C. punctipennis since it is generally considered a freshwater organism. Temperature generally showed a negative (but not significant) association with survival (Table D-17). All Chaoborus were collected well below the lethal threshold temperature of approximately 39 C (EA 1978b).

Entrainment survival estimates (Se) for Chaoborus punctipennis were near 100 percent both initially and at 24 hours:

	Initial	24 Hours
1975	99.1	98.4
1976	96.6	97.2
1978	109.5	110.5
Average	101.7	102.0

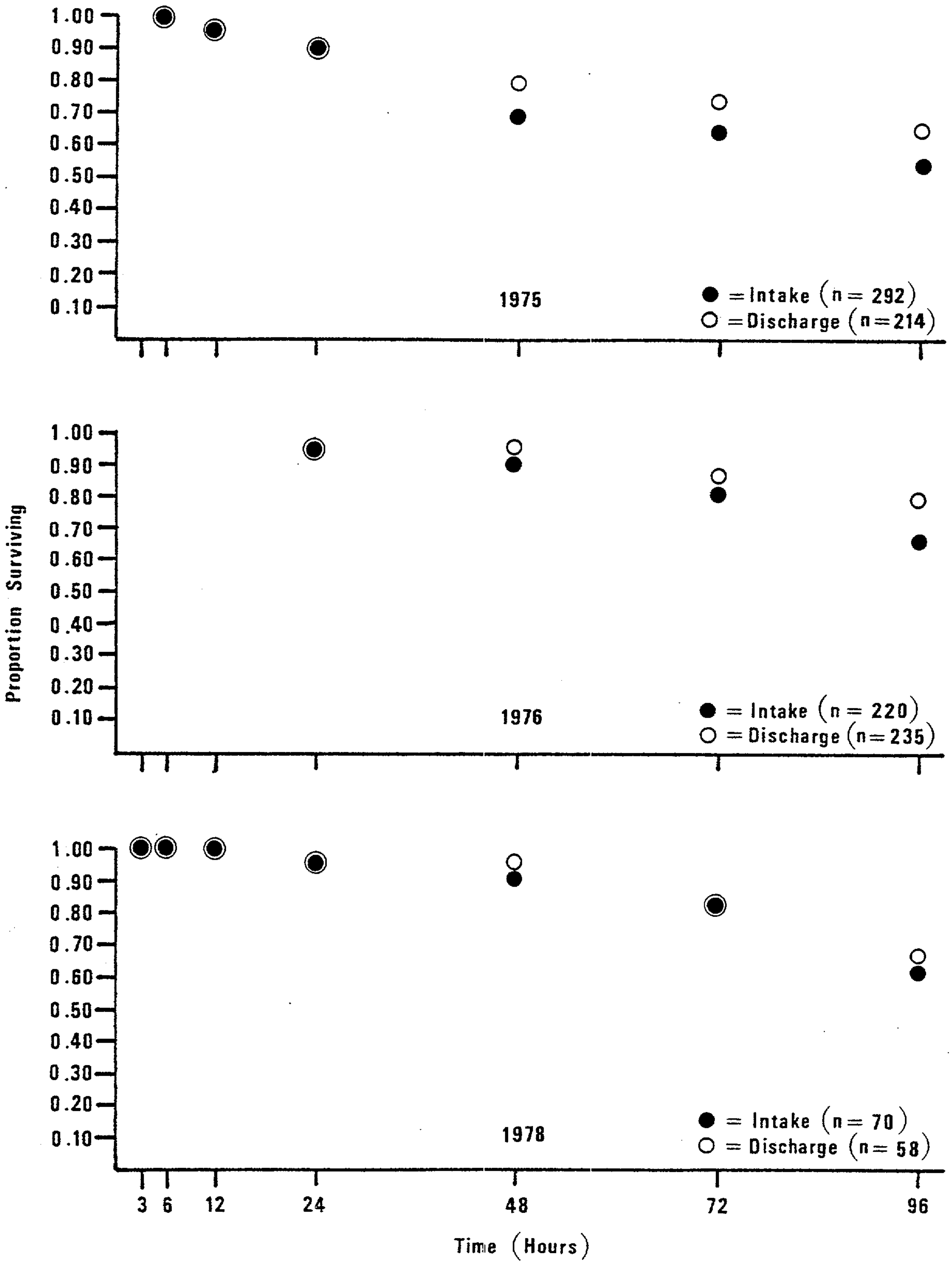

Figure 5-5. Survival curves during latent effects observation for Chaoborus punctipennis collected at the Bowline Point plant, 1975, 1976, and 1978.

Furthermore, no latent effects were apparent from comparison of initial and 24 hour Se's. Discharge temperature and pump mode did not appear to affect survival (Table 5-6).

5.3.2.5 Monoculodes edwardsi

Yearly differences exist in the initial proportion of Monoculodes edwardsi surviving (Tables D-18 and D-19) and therefore, the data collected in 1975 and 1976 could not be combined. The overall test of independence among years (1975 and 1976), stations (intake and discharge), and survival was highly significant; however, the year x survival term was the only two factor interaction found to be significant (Table D-20). No significant interaction among the three factors was observed.

Initial survival of Monoculodes edwardsi ranged from 0.702 to 0.929 at the intake and 0.707 to 0.944 at the discharge (Tables D-18 and D-19) of the Bowline Point plant. No significant difference in initial survival was found between the intake and discharge samples (Table D-20). Survival was higher at both stations during 1976 than in 1975.

Significant differences ($\alpha = 0.05$) in latent (24-hour) effects were observed between the intake and discharge for Monoculodes edwardsi (Table D-20). Extended survival was consistently lower for intake samples than discharge samples across the entire 96-hour latent effects observation period (Figure 5-6). The year x station x survival test for independence was significant; however, the test for interaction was not significant. Survival at 24 hours was 0.634 (1975) and 0.686 (1976) at the intake and 0.803 (1975) and 0.833 (1976) at the discharge.

Yearly entrainment survival (S_e) was 100.7 and 101.6 during 1975 and 1976 with a pooled estimate of 101.2 for Monoculodes edwardsi. No significant ($\alpha = 0.05$) correlations were observed between conductivity or temperature and initial or 24-hour survival (Table D-21). Temperature demonstrated a weak negative association with survival.

5.3.2.6 Crangon septemspinosa

Only twenty-five Crangon septemspinosa were collected during the three years of macrozooplankton sampling (Table D-22). Generally, only one or two Crangon were collected at a time, with collections occurring between July and October each year. Initial discharge survival was quite low (0.083); however, of the 12 organisms collected, nine dead were identified from samples on 16 October 1978. Extended survival (24-hour) was nearly always 100 percent for both intake and discharge samples. Assessment of thermal and mechanical power plant effects on Crangon septemspinosa survival could not be made because of the very low numbers of organisms collected.

5.3.2.7 Additional Macrozooplankton - 1975 and 1976

Twelve additional categories of non-RIS were collected during 1975 and 1976 for the evaluation of the total macrozooplankton community. Yearly summaries of the data on each species collected are presented in Tables D-23 through D-25. Most of these organisms were collected seasonally and in lower numbers than the previously described RIS.

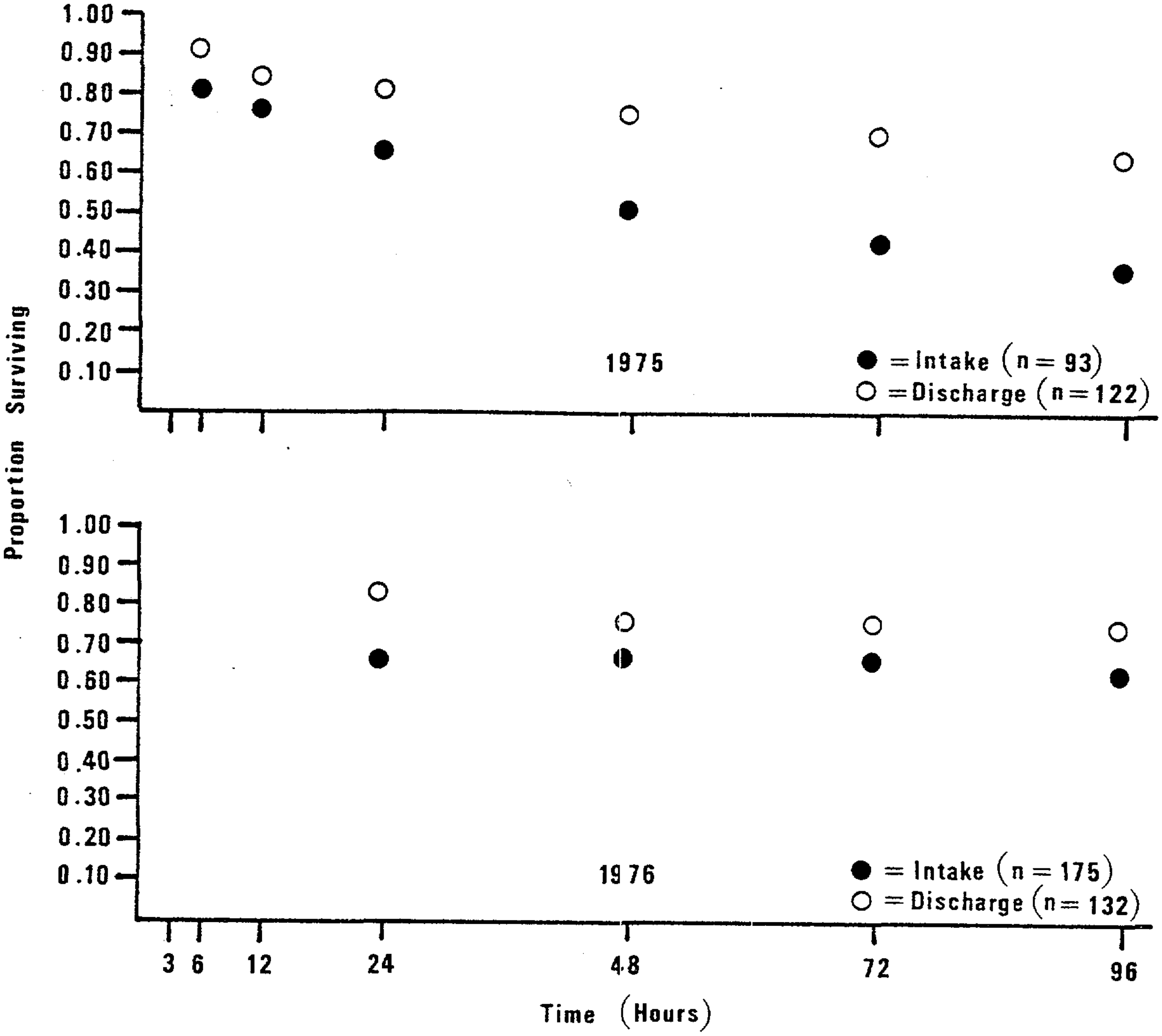

Figure 5-6. Survival curves during latent effects observations for *Monoculodes edwardsi* at the Bowline Point plant, 1975 and 1976.

While detailed examination of thermal and mechanical effects on survival of these taxa could not be performed (because of small sample sizes or limited variation in plant oprating condition during their entrainment season) overall entrainment survival generally exceeded 90 percent for taxa with more than 10 organisms at both stations (Tables D-23 to D-25).

5.3.2.8 Summary

The overall composition of the macrozooplankton community around the Bowline Point power plant remained relatively similar during 1975 and 1976 with about the same number of species present and Gammarus generally dominating (1975, 1976, and 1978). The sampling program during 1975 was designed to evaluate seasonal (summer, fall, and winter) survival with emphasis on the "worst" case, i.e., at the maximum discharge temperatures during the summer, 29 July -5 August. Sampling during 1976 was bimonthly from March to December, and as in 1975, was designed to evaluate the total macrozooplankton community. Sampling was from March through October 1978 and was concentrated on four RIS. Data on Gammarus, Neomysis americana, Chaoborus punctipennis, Crangon septemspinosa, and Monoculodes edwardsi were analyzed for yearly comparisons in initial and latent survival, as well as temperature, conductivity, and mechanical factors affecting survival. Additional species collected during 1975 and 1976 were addressed, but in less detail.

Both initial and latent (24-hour) survival generally were significantly different ($\alpha = 0.05$) among the three years (1975, 1976, and 1978) for the four organisms (Gammarus, Neomysis, Chaoborus, and Monoculodes) tested. Only Monoculodes, during latent survival, did not significantly differ between years, however, only 1975 and 1976 data were available. Survival was generally lowest for most organisms during 1975, as expected, since sampling in 1975 was concentrated during the summer season when temperatures were highest in order to examine the maximum thermal effects. This different emphasis in sampling design probably contributed the most to cross-year variability which prevented the pooling of data across years.

No significant difference was found in initial survival between samples collected at the intake or discharge stations for Gammarus, Neomysis, Chaoborus, or Monoculodes. Extended (24-hour) survival differences existed in three of the four (not Chaoborus) species tested with Gammarus and Neomysis having lower survival for samples collected at the discharge.

Temperature was generally negatively associated with survival, but correlations were seldom statistically significant. Discharge temperatures seldom exceeded 35 C and only Neomysis appeared strongly stressed as temperatures approached 35 C. Conductivity and survival were only associated positively with saline species like Neomysis and negatively with freshwater species like Chaoborus. Sample size limitations restricted statistical comparison for mechanical stress (full versus throttled pump operation modes) to Gammarus. Gammarus initial survival at the discharge station was significantly higher when the two circulating pumps were operating in the full vs. throttled modes.

Yearly entrainment survival (S_e) estimates were generally over 95 percent, as expected, since no differences were found between intake and discharge stations in initial survival of *Gammarus*, *Neomysis americana*, *Chaoborus punctipennis*, and *Monoculodes edwardsi*. *Neomysis americana* demonstrated a decrease in entrainment survival as the discharge temperatures increased and between full and throttled operation modes of the circulation pumps.

CHAPTER 6: ICHTHYOPLANKTON ENTRAINMENT

6.1 INTRODUCTION

Studies were conducted at the plant intake and discharge between 1975 and 1979 to assess the impact of the once-through cooling system on entrained ichthyoplankton at the Bowline Point Generating Station. These studies have included monitoring of abundance and evaluation of survival for wild and hatchery-reared ichthyoplankton:

Year	Discipline	Intake	Discharge Standpipe	Discharge Diffuser
1975	Abundance	x		
	Survival	x	x	
1976	Abundance	x		
	Survival	x	x	
1977	Abundance	x	x	
	Survival	x	x	
	Direct Release	x	x	
1978	Abundance	x	x	
	Survival	x	x	x
	Direct Release	x	x	x
1979	Abundance	x	x	
	Survival	x	x	x
	Direct Release	x	x	x

Although these studies have concentrated on the most abundant taxa and species identified as representative important species (RIS), information on involvement and survival has been generated for most of the ichthyoplankton entrained at the plant. The studies have also sought to identify the major environmental, biological, and plant operating factors which influence involvement and survival. This information has been used in conjunction with thermal laboratory data to develop a mathematical model for historical and predictive estimation of entrainment mortality factors (fc), which are in turn used to calculate conditional mortality rates.

Supplementary studies have been conducted to provide information on specific aspects of the entrainment process and sampling program. These include: calibration of the sampling gear to quantify sampling stress; evaluation of the influence of the diffuser discharge on survival through use of a scale model; and evaluation of a model, angled, fine-mesh intake screen for reducing entrainment losses.

Ecological Analysts, Inc., has reported the results of these programs in a series of reports prepared for Orange and Rockland Utilities, Inc.:

1. Bowline Point Generating Station Entrainment Survival and Abundance Studies. 1975 Annual Interpretive Report. 1976.
2. Bowline Point Generating Station Entrainment and Impingement Studies. 1976 Annual Report. 1977.
3. Bowline Point Generating Station Entrainment Survival Studies. 1979 Annual Report. 1978.

4. Bowline Point Generating Station Entrainment Abundance Studies. 1977 Annual Report. 1978.
5. Bowline Point Generating Station Entrainment Abundance and Survival Studies. 1978 Annual Report. 1979

For detailed information on each of these annual studies, the reader is referred to these documents. This report will provide a detailed analysis of the studies conducted during 1979 (for which no separate annual report has been prepared) and a summary and analysis of the entire five-year data base.

6.2 ENTRAINMENT ABUNDANCE

6.2.1 Introduction

Entrainment abundance studies have been conducted at the Bowline Point plant from 1975 through 1979 to assess involvement of ichthyoplankton in the once-through cooling system of the plant. Information on involvement obtained from these studies is used in conjunction with data from the river to evaluate abundance of entrained organisms relative to river-wide and local populations, and with entrainment survival data to evaluate overall susceptability of the population to the stresses of entrainment. Species and life stage composition, seasonal densities, length frequency, diel distribution, and differences between Units 1 and 2 were examined as part of these studies. The primary emphasis was on striped bass, white perch, Atlantic tomcod, bay anchovy, and clupeids. Abundance has been studied independently at the intake and discharge since 1976 and at the intake alone in 1975. The sampling gear, procedures, and frequency evolved between 1975 and 1979 in order to optimize sampling effort at the time of peak entrainment for the key taxa (Table 6-1).

6.2.2 Methods and Materials

6.2.2.1 Overview of Collection Procedures from 1975 through 1979

Discharge samples were collected with an automatic pumped sampler (Figure 6-1) which provided continuous 24-hour data throughout the peak periods of entrainment and estimates of diel distributions of ichthyoplankton. With this system, water was pumped from the discharge standpipe by a 7.6-cm (3-in.) electric pump. Samples were collected in a cylindrical plankton net (505-µm bar mesh) mounted in a tank 1 m in diameter and 1.2 m deep. The pump automatically shut down every hour for approximately 2 minutes during the net rinse cycle. After each rinse, the sample was concentrated and preserved with 10 percent formalin. One-hour samples were then composited to obtain one 24-hour sample or eight 3-hour samples (diel series). After each collection period (3 or 24 hours), the sample was transferred to a labeled 800-ml glass jar and preserved with 10 percent formalin. Sample volumes were measured with a calibrated 7.6-cm (3-in.) inline flowmeter. The sample duration and number of cycles were automatically registered by a mechanical recorder. Ambient water temperature, conductivity, dissolved oxygen, and pH were monitored at the beginning and end of each sample. Samples were collected on from one to six days a week, depending on the year and ichthyoplankton abundance (Table 6-1).

TABLE 6-1 SUMMARY OF THE PRIMARY CHANGES IN THE ENTRAINMENT ABUNDANCE SAMPLING PROGRAM MADE AT THE BOWLINE POINT PLANT FROM 1975 TO 1978

Year	Station	Sampling Device(a)	Sampling Season	Sampling Frequency	Diel Schedule(b)	Sample Duration (min)	Sample Depth(c)	Flowmeter
1975	Intake	505-μm net	FEB-OCT	1 day/week	N,S,M,S	5-90(d)	S,M,B	G.O. mechanical(e)
1976	Intake	505-μm net	FEB-SEP	1 day/week	N,S,M,S	30	S,M,B	G.O. mechanical(e)
	Intake	4-in. pump manifold	FEB-SEP	1 day/week	N,S,M,S	30	S,M,B	In-line
	Discharge	3-in. pump 505-μm net	JUN-AUG	1-4 days/week	Sunset	3 hours	1 m into 3.2-m diameter discharge pipe	In-line
1977	Intake	505-μm net	FEB-AUG	1-2 days/week	N,M	6-30	S,M,B,	G.O. mechanical(f) Cushing electromagnetic
	Discharge	Autosampler 3-in. pump 505-μm net	FEB-AUG	4-6 days/week	8 3-hour samples(h)	24 hours	1 m into 3.2-m diameter discharge pipe	In-line
1978	Intake	571-μm net	FEB-AUG	1-2 days/week	N,M	30	S,M,B	Cushing electromagnetic(g)
	Discharge Unit 1	Autosampler 3-in. pump 505-μm net	FEB-AUG	3-4 days/week	8 3-hour samples(i)	24 hours	1 m into 3.2-m diameter discharge pipe	In-line
	Discharge Unit 2	Autosampler	MAR-AUG	2 days/week		24 hours	1 m into 3.2-m diameter discharge pipe	In-line
1979	Intake	571-μm net	MAR, MAY-JUL	1-2 days/week	N,M	30	S,M,B	Cushing electromagnetic(g)
	Discharge	Autosampler 3-in. pump 505-μm net	MAR, MAY-JUL	5 days/week	8 3-hour samples(i)	24 hours	1 m into 3.2-m diameter discharge pipe	In-line

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(a) All intake nets are 0.5-m conical plankton nets, 1.9-m long, with a porosity of 50 percent.
(b) N,S,M,S = noon, sunset, midnight, sunrise.
(c) S,M,B = surface, middepth, bottom.
(d) Sample duration was changed during 1975 to determine optimal duration which would minimize net clogging and maximize sample volume.
(e) Volume calculated from velocity matrix, duration, and area of net mouth; flowmeter used to identify, and void clogged samples.
(f) One Cushing and two G.O. meters rotated between three depths. Cushing meter data used to create velocity matrix.
(g) Cushing meter in each net used to determine volume of samples.
(h) Diel sampling occurred on 1 day each week during peak abundance; all other days were 24-hour composites.
(i) Diel sampling occurred at least 1 day each week and on 2 days during peak abundance; all other days were 24-hour composites.

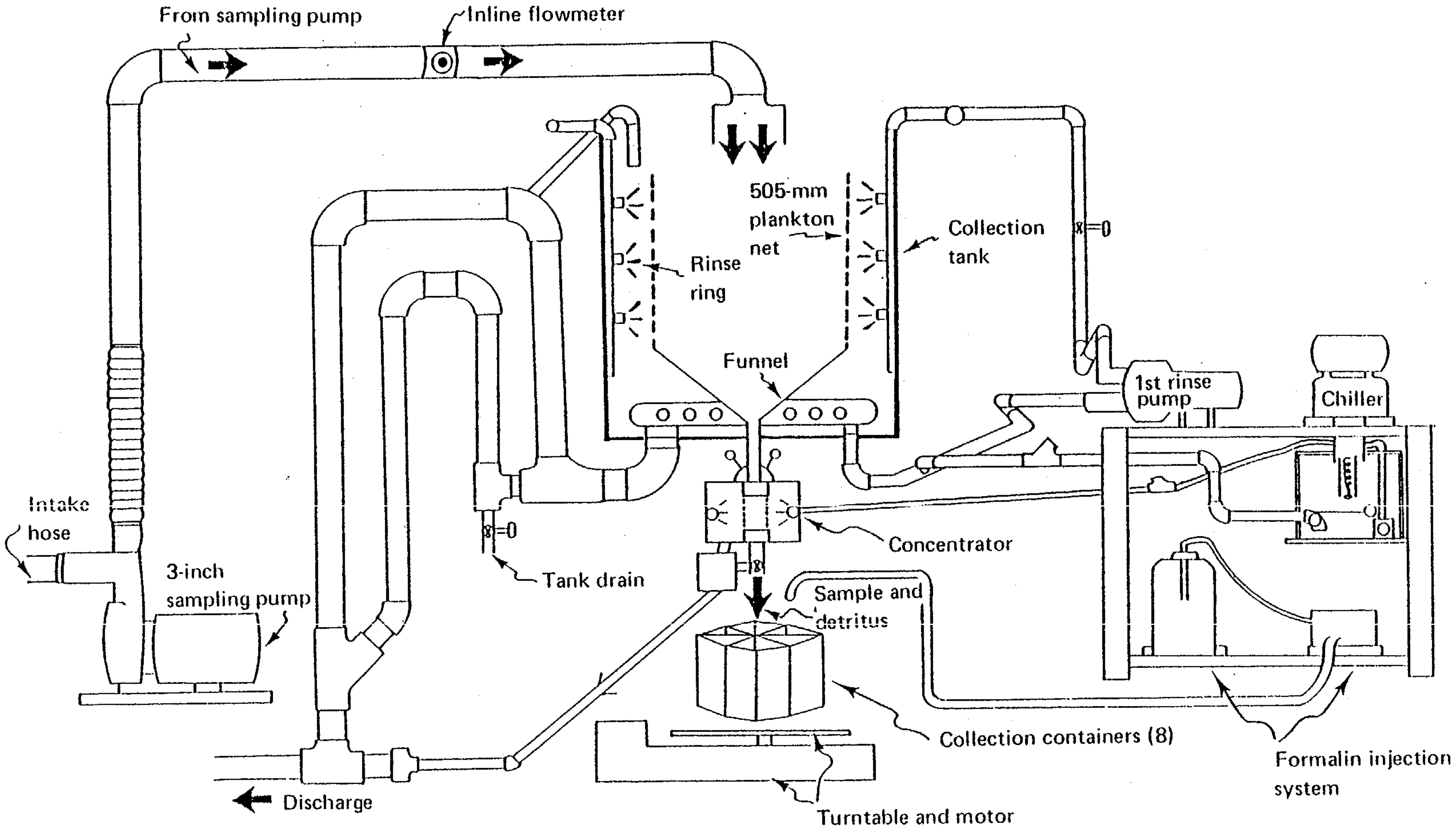


Figure 6-1. Schematic diagram of sampling components of Ecological Analysts' automated abundance sampling system – AUTOSAM (U.S. Patent No. 4, 145, 925).

Samples were collected at the surface, middle, and bottom depths at the intake in an attempt to account for vertical stratification of ichthyoplankton. Plankton nets 0.5 m in diameter and 1.9 m long were used to meet clearance limitations at the intake structure. The net mesh opening was changed from 505 to 571 µm in 1978; however, this change did not affect the porosity (50 percent) of the nets. The nets were mounted on a rigid frame parallel to and in front of the Unit 1 trash racks (Figure 6-2) and samples began and ended when the surface net reached the water surface. Two consecutive 30-minute samples were collected at both noon and midnight; additional sets of samples were collected at dawn and dusk in 1975 and 1976. In 1975, sample durations varied between 5 and 90 minutes during studies to determine the optimal duration to prevent clogging and maximize sample volume. Prior to 1978, sample volumes were estimated using a velocity matrix over tide and plant pump operation. Flowmeters were used to identify and void clogged samples. In 1978 and 1979, a Cushing electromagnetic flowmeter was used to determine the volume for each sample. The mean velocity for the samples at each depth was calculated from velocity measurements taken at 5-minute intervals throughout the sample. At the completion of each 30-minute collection period, the nets were thoroughly rinsed into the codend. The samples were then transferred to labeled 800-ml glass jars and preserved with 10 percent formalin.

Preserved samples were transported to laboratory facilities for workup and quality control analysis. In the laboratory, samples were transferred to blackened Pyrex trays, sorted, and enumerated by life stage. Ichthyoplankton specimens were removed from each sample, placed in vials according to life stage, and preserved with 5 percent formalin. Each specimen was identified to family or species with emphasis on the most abundant species. Because of the difficulty involved in differentiating the early life stages of alewife and blueback herring, these two species were grouped under the name clupeids. American shad and other species in the family Clupeidae were identified to the species level. Identification was facilitated by available literature (Table 6-2) and an ichthyoplankton reference collection.

The identification of rare or unusual specimens was verified by a specialist in ichthyoplankton taxonomy. Length was measured on selected diel and net samples and the most abundant species. Quality control procedures were applied to both sorting and identification (proportion defective analysis). This was an acceptance sampling procedure which randomly selects a portion of the samples for rework. The procedure provides an average outgoing quality level (AOQL) with an error rate of no more than 10 percent.

6.2.2.2 1979 Studies

During the 1979 entrainment study, samples were collected throughout March and from 20 May through 14 July (Table 6-3). Instead of the 24- and 3-hour discharge samples described above, two 2-hour samples were collected each day from 20 May through 9 June. During this period, the Bowline Point plant was offline and two cooling water pumps were operated for part of the day to permit sampling. The 2-hour samples were made during the day and at night and timed to coincide with intake and river sampling (at approximately 1300 and 2100 hours on two days each week).

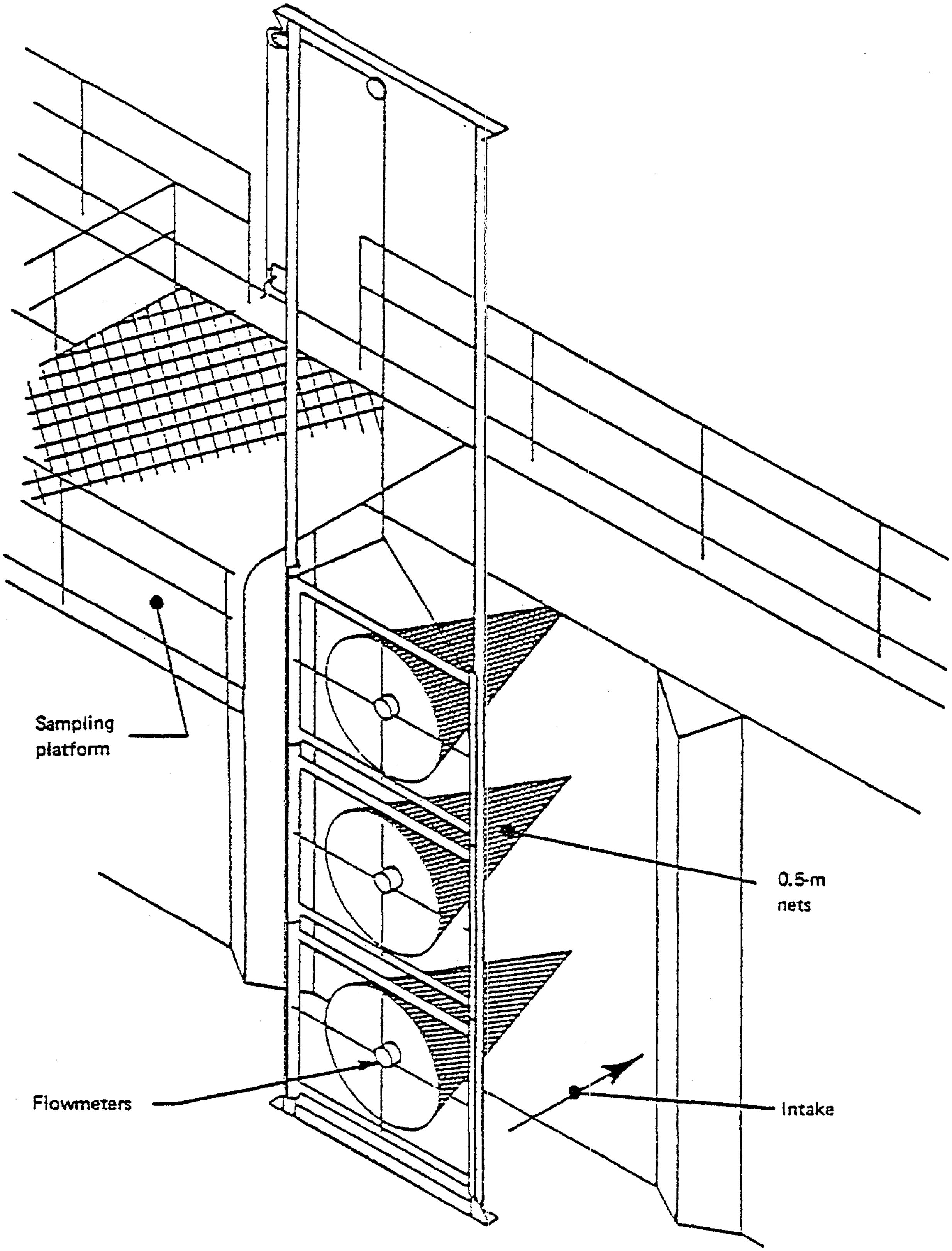


Figure 6-2. Schematic representation of the sampling apparatus used to determine ichthyoplankton abundance at the intake.

TABLE 6-2 LIST OF PRIMARY LITERATURE SOURCES USED IN LABORATORY IDENTIFICATION OF ICHTHYOPLANKTON

Chambers et al. 1969
Cianci 1969
Mansueti and Hardy 1967
Scotten et al. 1973
Leim 1924
Lippson and Moran 1974
Hildebrand and Schroeder 1928
Bigelow and Schroeder 1953
Booth 1967
Mansueti 1958
Bayless 1972
Doroshev 1970
Rathjen and Miller 1957
Dovel and Edmonds 1971
Krester 1968
Bath 1974
Wang and Kernehan 1979

TABLE 6-3 SUMMARY OF THE NUMBER OF ABUNDANCE SAMPLES COLLECTED AT THE BOWLINE POINT PLANT IN 1979

	Discharge			Intake
Date	24-Hour	Diel(a)	2-Hour(b)	Unit 1 Day/Night(c)
4-10 MAR	4	1		1
11-17 MAR	4	1		1
18-24 MAR	4	1		1
25-31 MAR	4	1		1
20-26 MAY			4	2
27 MAY - 2 JUN			3	2
3-9 JUN			4	2(d)
10-16 JUN	3	2		2(d)
17-23 JUN	2	2		2(d)
24-30 JUN	3	2		2
1-7 JUL	3	2		2
8-14 JUL	3	2		1

(a) Diel surveys consist of eight 3-hour samples collected in a single 24-hour period.

(b) Between 20 May and 9 June sampling consisted of two 2-hour samples taken at the same time that the intake nets were sampled, because the plant was down and limited the amount of time for sampling.

(c) For days sampled at the intake there were two consecutive 30-minute samples for surface, middle, and bottom depths taken at noon and midnight.

(d) Between 7 June and 21 June samples consisted of three 10-minute composites for a 30-minute sample, because of clogging observed during that time.

High densities of filamentous algae necessitated reduction of intake sample durations to 10 minutes from 7 June through 21 June to avoid net clogging. Three 10-minute samples were composited to obtain the standard 30-minute samples during this period.

Although common names will be used in this report, a list of common and scientific names has been included (Table 6-4) for clarity and for the convenience of the reader.

6.2.3 Results and Discussion

6.2.3.1 1979 Discharge Sampling

Entrainment abundance and species composition were determined from the 24-hour samples collected at the discharge. The majority of the organisms collected during 1979 were the early life stages of anadromous or migratory estuarine taxa (i.e., bay anchovy, Atlantic tomcod, striped bass, clupeids and white perch) which spawn during spring and early summer. Post yolk-sac were predominant in discharge samples (72.6 percent) followed by eggs (8.1 percent). Bay anchovy accounted for 56.6 percent of all ichthyoplankton entrained during 1979 (Table 6-5). The next four most abundant taxa were Atlantic tomcod, white perch, striped bass, and Clupeids. These five taxa constituted 89.9 percent of the collections. Rainbow smelt eggs were also abundant during 1979, composing 4.7 percent of the total catch.

6.2.3.1.1 Bay Anchovy

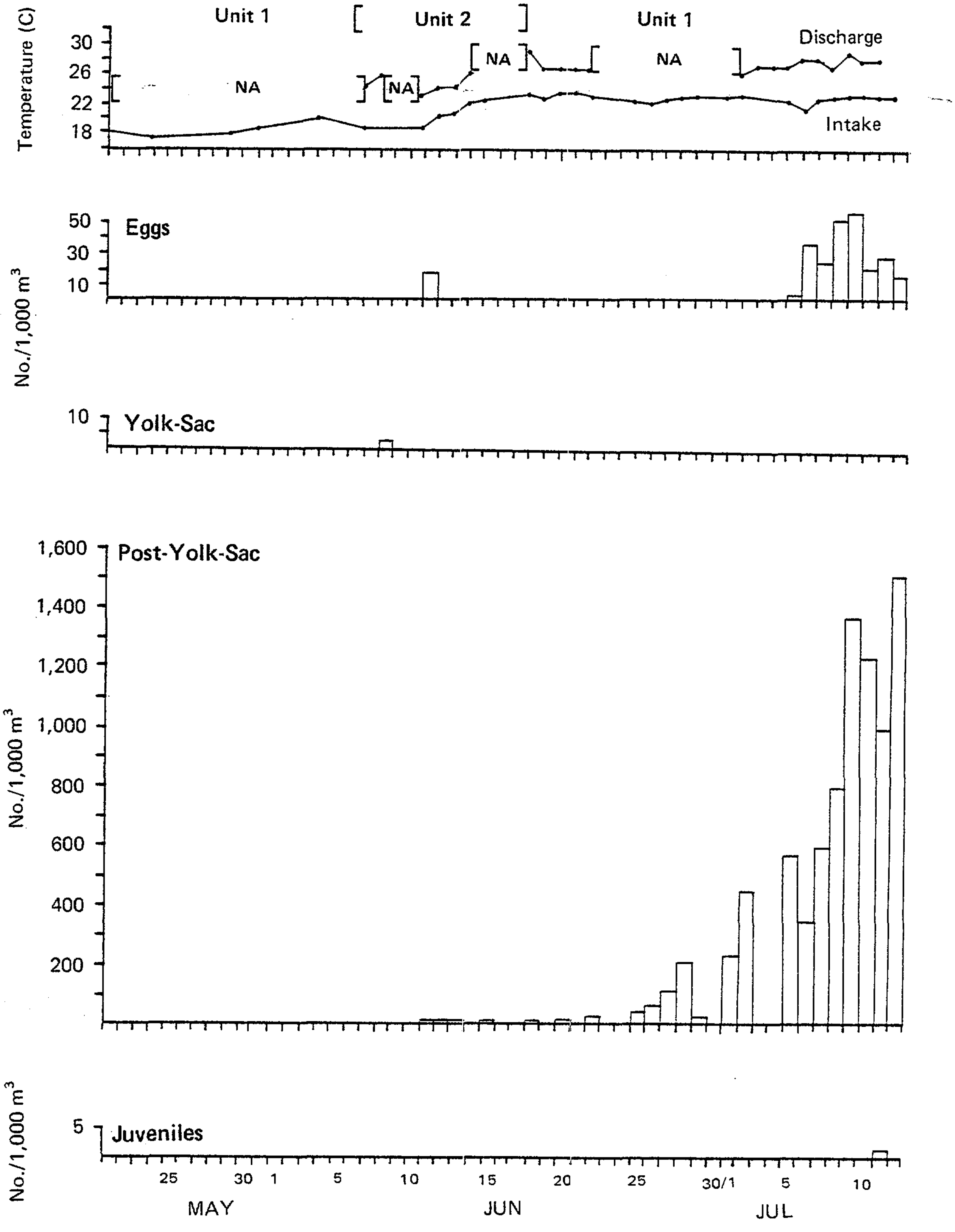
Bay anchovy spawn in the high salinity portion of the Hudson River throughout the summer, and eggs were collected in June and early July until the end of scheduled sampling in mid-July (Figure 6-3, Appendix E, Table E-1). Bay anchovy post yolk-sac larvae were present from late June through the end of the sampling effort. Ambient water temperature during this period ranged from 20 to 24 C. Entrained bay anchovy ranged from 2 to 65 mm in length (Table F-1). Larvae from 6.0 to 8.9 mm were the most abundant length group and constituted 25 percent of all anchovy collected at the discharge (Figure 6-4); the remaining bay anchovy were distributed evenly from 3 to 24 mm. The length frequency of bay anchovy entrained during 1979 was similar to 1978 (EA 1979a), skewed slightly toward smaller organisms. However, because of the short sampling season, the abundance of larger organisms may not be accurately represented. The peak probably occurred in late July for yolk-sac and post yolk-sac larvae, similar to 1978. Bay anchovy post yolk-sac larvae exhibited slightly higher densities at night and lowest densities during the afternoon (Figure 6-5, Table G-1). This pattern was similar to that observed during 1977 and 1978 when higher densities occurred between 2100 and 0900 hours; however, the peaks were not as distinct as in previous years. When the entrained population is examined by 3-mm length groups, two distinct diel patterns are apparent (Figure 6-6). Bay anchovy in the two smaller length classes (3-9 mm) were more abundant during the day with minimum densities from 1800 to 0300 hours; the two larger length classes were most frequently collected from 1800-0300 hours. The intermediate length classes (9-20 mm) were variable in distribution.

TABLE 6-4 LIST OF COMMON AND SCIENTIFIC NAMES OF THOSE TAXA COLLECTED IN ENTRAINMENT ABUNDANCE SAMPLES AT THE BOWLINE POINT PLANT

Family	Genus Species	Accepted Common Name
Anguillidae	*Anguilla rostrata*	American eel
Clupeidae		Herring
	Alosa aestivalis	Blueback herring
	Alosa sapidissima	American shad
Engraulidae		Anchovy
	Anchoa mitchilli	Bay anchovy
Osmeridae	*Osmerus mordax*	Rainbow smelt
Cyprinidae		Minnow and carp
	Notropis hudsonius	Spottail shiner
Gadidae	*Microgadus tomcod*	Atlantic tomcod
Belonidae	*Strongylura marina*	Atlantic needlefish
Cyprinodontidae	*Fundulus* spp.	Killifish
Atherinidae	*Menidia* spp.	Silverside
Syngnathidae	*Syngnathus fuscus*	Northern pipefish
Percichthyidae	*Morone* spp.	Temperate bass
	Morone americana	White perch
	Morone saxatilis	Striped bass
Centrachidae		Sunfishes
	Micropterus salmoides	Largemouth bass
Percidae		Perch
	Etheostoma olmstedi	Tessellated darter
	Perca flavescens	Yellow perch
	Stizostedion vitreum	Walleye
Pomatomidae	*Pomatomus saltatrix*	Bluefish
Sciaenidae	*Cynoscion regalis*	Weakfish
Soleidae	*Trinectes maculatus*	Hogchoker
Pleuronectidae	*Pseudopleuronectes americanus*	Winter flounder

TABLE 6-5 NUMBER AND PERCENT COMPOSITION BY TAXA AND LIFE STAGE OF ORGANISMS ENTRAINED AT THE BOWLINE POINT PLANT DISCHARGE, 1979

Species	Eggs	YSL	PYSL	JUV	UID	Total	%
Bay anchovy	134	2	5,088			5,224	57.6
Atlantic tomcod		92	236		980	1,236	13.6
White perch	136	65	337	13		551	6.1
Striped bass		122	333	88		543	6.0
Morone spp.		3	384	2	125	514	5.7
Rainbow smelt	431		2	5		438	4.8
Silversides		63	90			153	1.7
Unidentifiable	5			1	130	136	1.5
Clupeids			89			89	1.0
Sunfish		56	20			76	0.8
Minnow	25	30	5			60	0.7
American eel				4		44	0.5
American shad			3			3	<0.1
Killifish	1	1	1			3	<0.1
Tessellated darter				2		2	<0.1
Hogchoker		1				1	<0.1
Northern pipefish				1		1	<0.1
Atlantic needlefish				1		1	<0.1
Total	732	435	6,588	157	1,163	9,075	
Percent of total	8.1	4.8	72.6	1.7	12.8		



NA — Unit offline; no discharge temperature available.

Figure 6-3. Seasonal distribution of bay anchovy at the Bowline Point plant discharge during entrainment abundance studies, 1979.

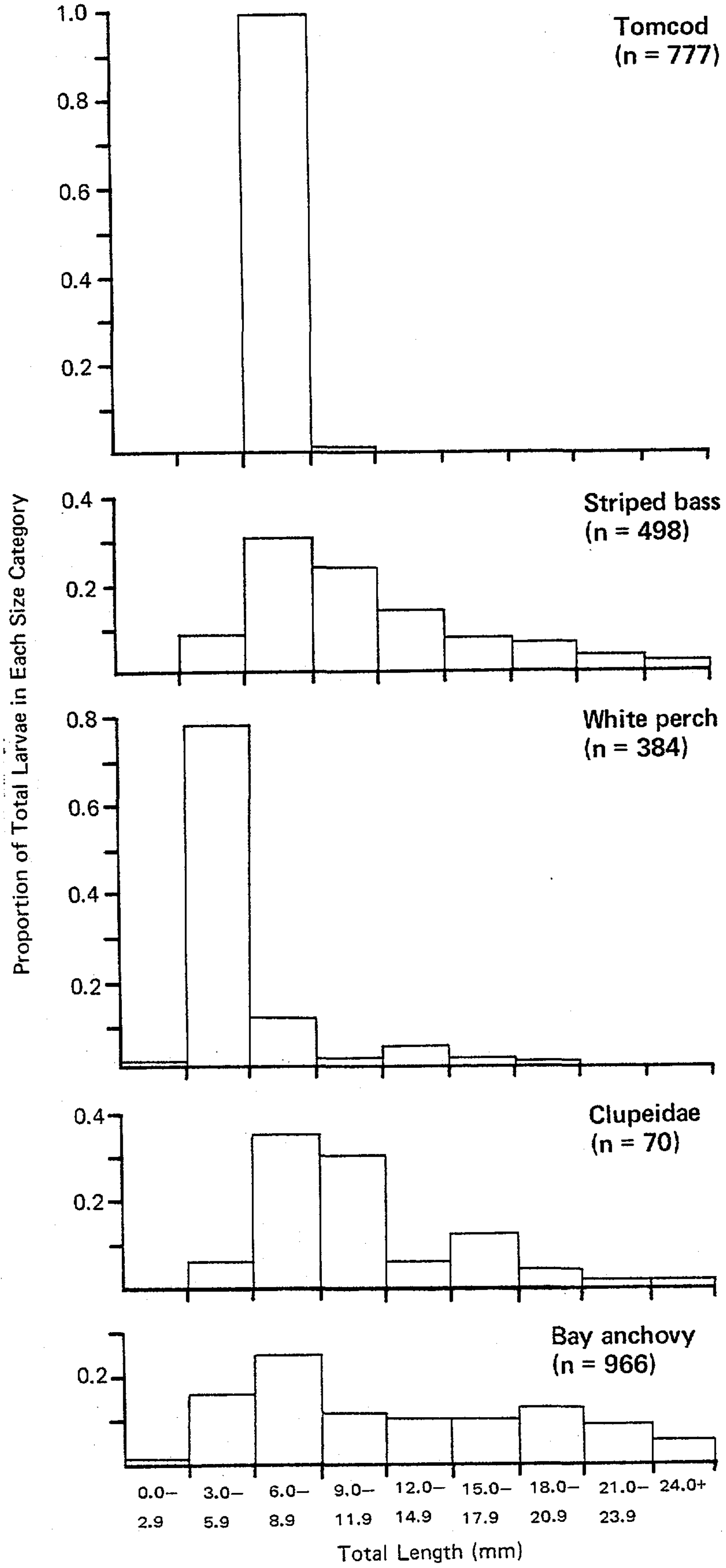
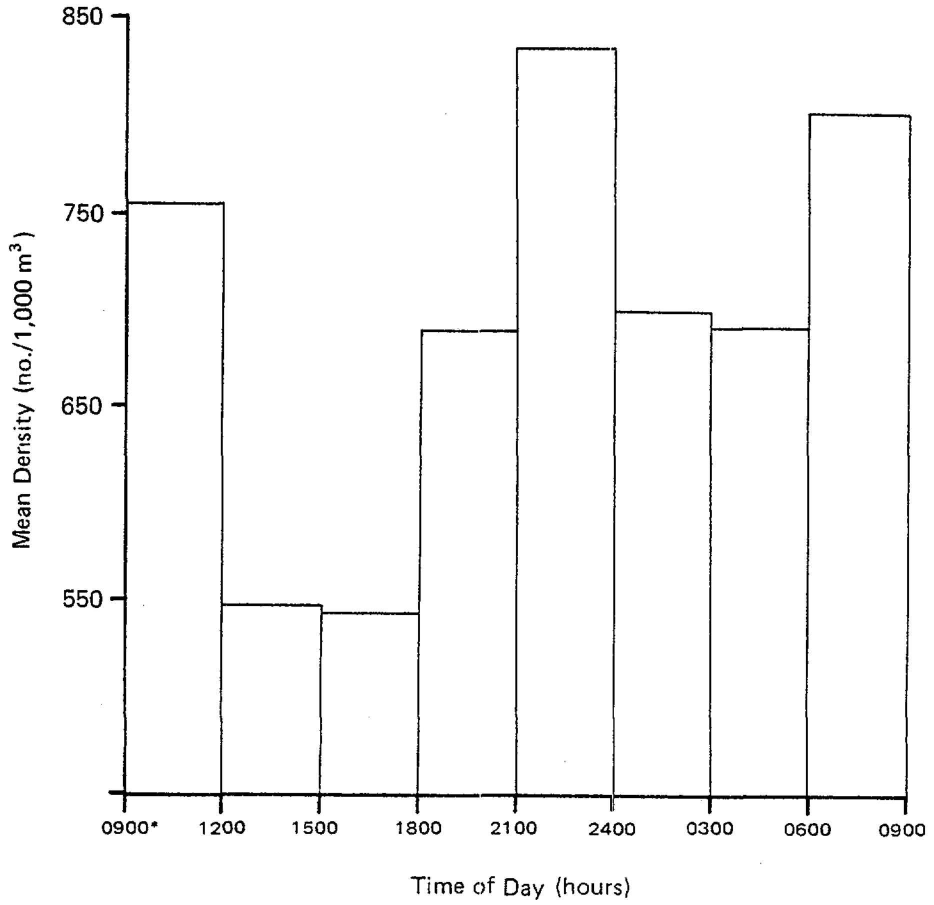


Figure 6-4. Length-frequency distribution of fish larvae collected at the Bowline Point plant discharge during entrainment abundance studies, 1979.



* Indicates sample start time.

Figure 6-5. Diel distribution of bay anchovy post-yolk-sac larvae at the Bowline Point plant discharge during entrainment abundance studies, 1979.

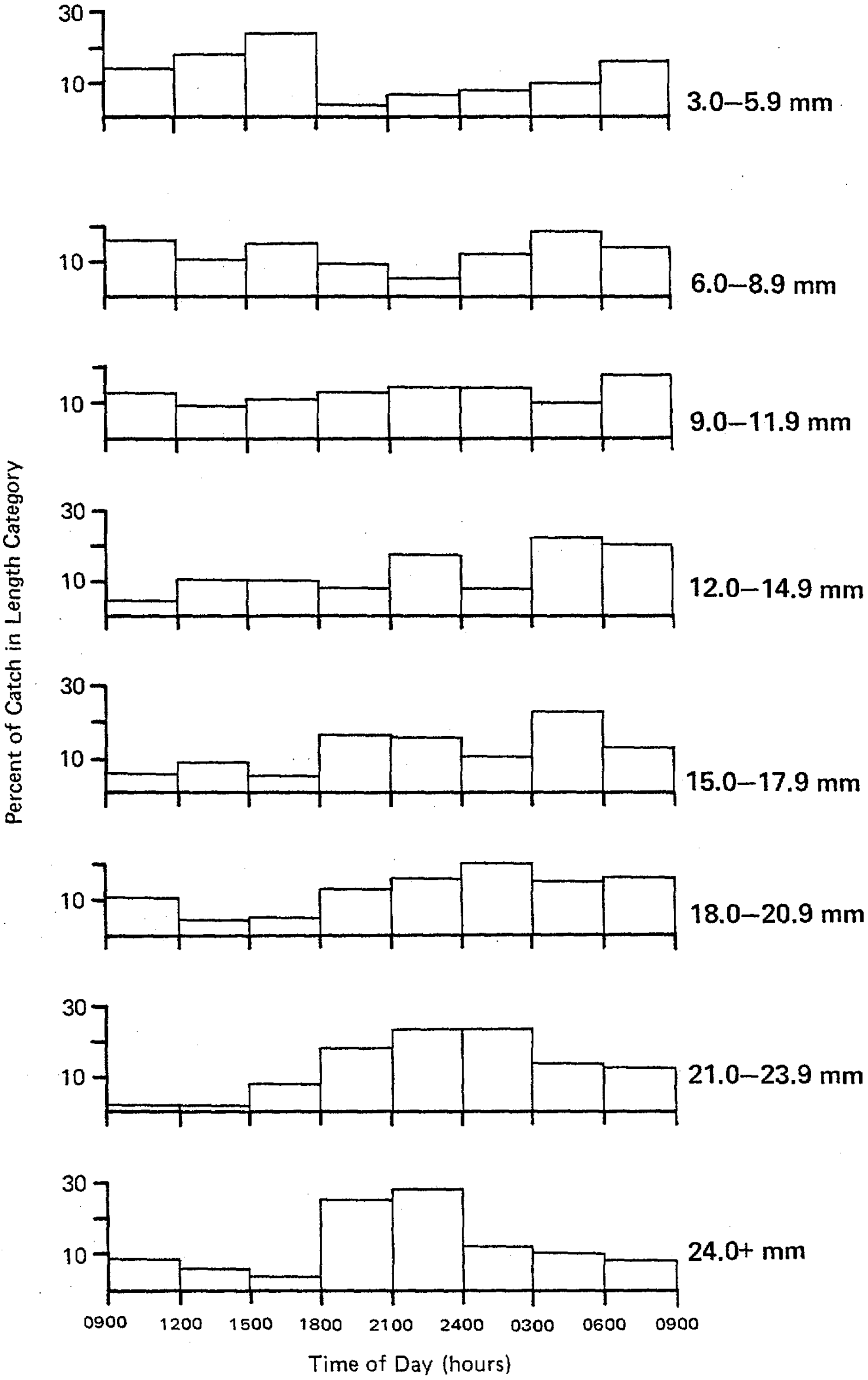


Figure 6-6. Mean diel length distribution for bay anchovy at the Bowline Point plant discharge during entrainment abundance studies, 1979.

6.2.3.1.2 Atlantic tomcod

Atlantic tomcod larvae were collected at the Bowline Point plant discharge from early March until the end of March, with peak densities of yolk-sac larvae during the third week and post yolk-sac larvae during the last week of March (Figure 6-7, Table E-2). The maximum density of yolk-sac and post yolk-sac larvae in 1979 was approximately half that observed in 1978. Conductivity during the 1979 peak was much lower (less than 200 μmhos/cm), which may have been responsible for a shift in the river-wide distribution of tomcod larvae between these years. Yolk-sac and post yolk-sac larvae were collected at ambient temperatures from 0.4 to 5.0 C and discharge temperatures from 7 to 13 C. Juveniles were not collected during 1979; however, based on data from previous years, juveniles would not be expected to occur until early May when sampling did not occur. The length frequency of Atlantic tomcod was similar to that observed in 1977 and 1978 (Figure 6-4, Table F-2). Larvae measuring 6-9 mm consitituted 99 percent of all Atlantic tomcod measured. The diel distribution of tomcod larvae exhibited a minimum abundance between 1800 and 2100 hours and peak abundance between 0300 and 1500 hours (Figure 6-8, Table G-2).

6.2.3.1.3 White Perch

White perch spawn during late spring in the Hudson River and eggs were most abundant at the discharge during the last week of May when ambient water temperature was 17-20 C (Figure 6-9, Table E-3). Because the unit was offline, discharge temperatures were approximately the same as ambient river temperatures and the density of eggs was lower than 1977 and 1978. The abundance of yolk-sac and post yolk-sac larvae was lower in 1978 but higher than 1977.

Larvae measuring 3-6 mm constituted 78 percent of all white perch collected (Figure 6-4, Table F-3). The same length category was most abundant in 1977 and 1978, but larvae were distributed more evenly from 3 to 18 mm during 1977.

White perch yolk-sac larvae were collected in a bimodal distribution with peaks in abundance at 1500-1800 and 0300-0600 hours (Figure 6-10, Table G-3). Post yolk-sac larvae exhibited a diel pattern of entrainment with peak density between 2400-0300 hours. The smaller length groups (3-9 mm) were abundant throughout the day with a slight increase in abundance between 1500-0600 hours (Figure 6-11). White perch larger than 9 mm were infrequently collected during daylight, with peak densities occurring between 2400 and 0600 hours.

6.2.3.1.4 Striped Bass

Similar to white perch, striped bass larvae were collected from the end of May through the beginning of July; however, no eggs were collected. Peak densities of yolk-sac larvae and post yolk-sac larvae (Figure 6-12, Table E-4) occurred during the third, fourth, and fifth week of June, respectively. During this period, ambient water temperature was 19-24 C and discharge temperature was 23-29 C when the unit sampled was online; otherwise discharge temperatures were at or slightly above ambient temperatures. The peak abundance of yolk-sac and post yolk-sac larvae was approximately one-half that observed in 1977 and 1978 and occurred one week later than in 1978 (EA 1978c). Spring river temperatures during 1978 were approximately 2 weeks ahead of those observed

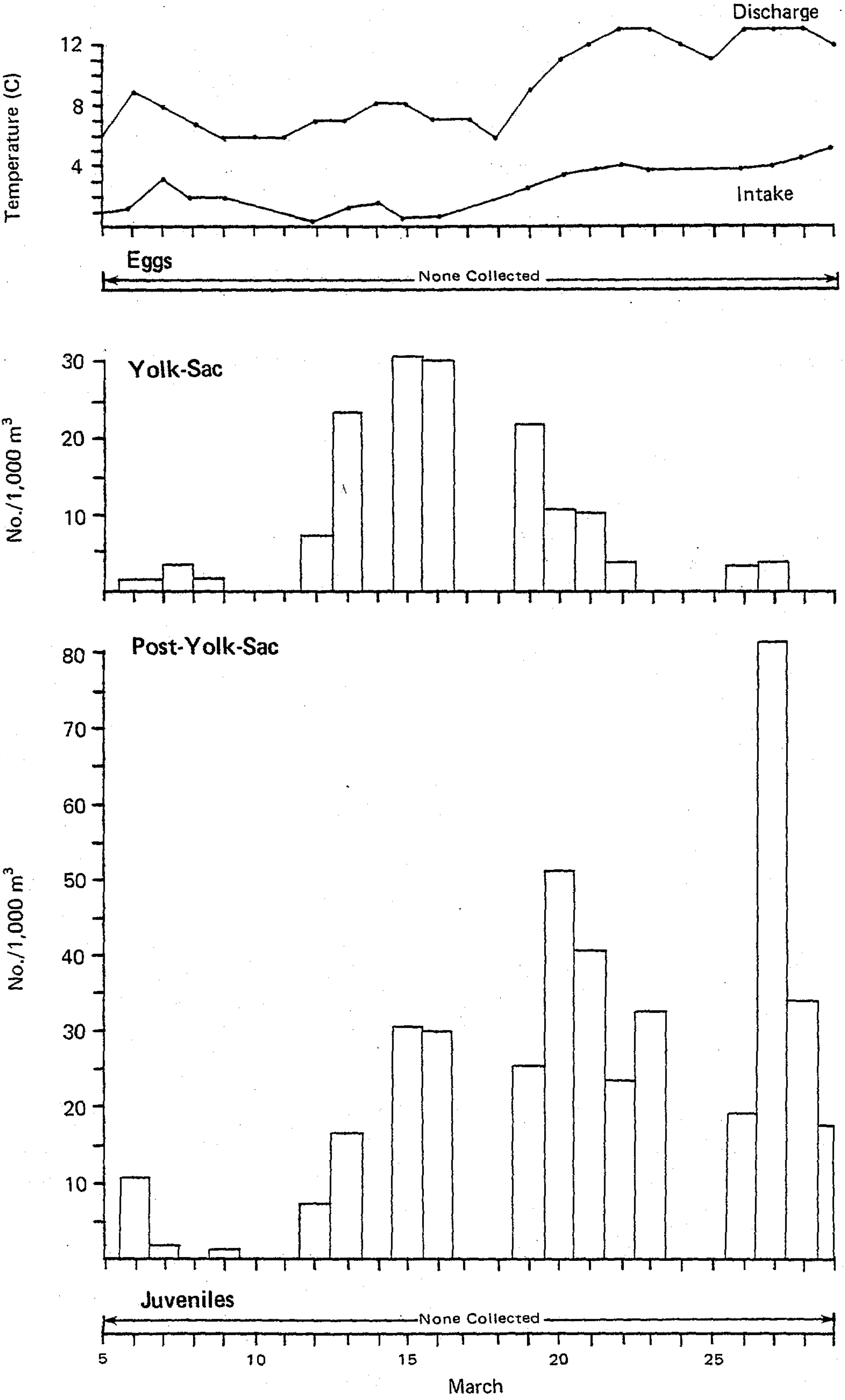


Figure 6-7. Seasonal distribution of Atlantic tomcod at the Bowline Point plant discharge during entrainment abundance studies, 1979.

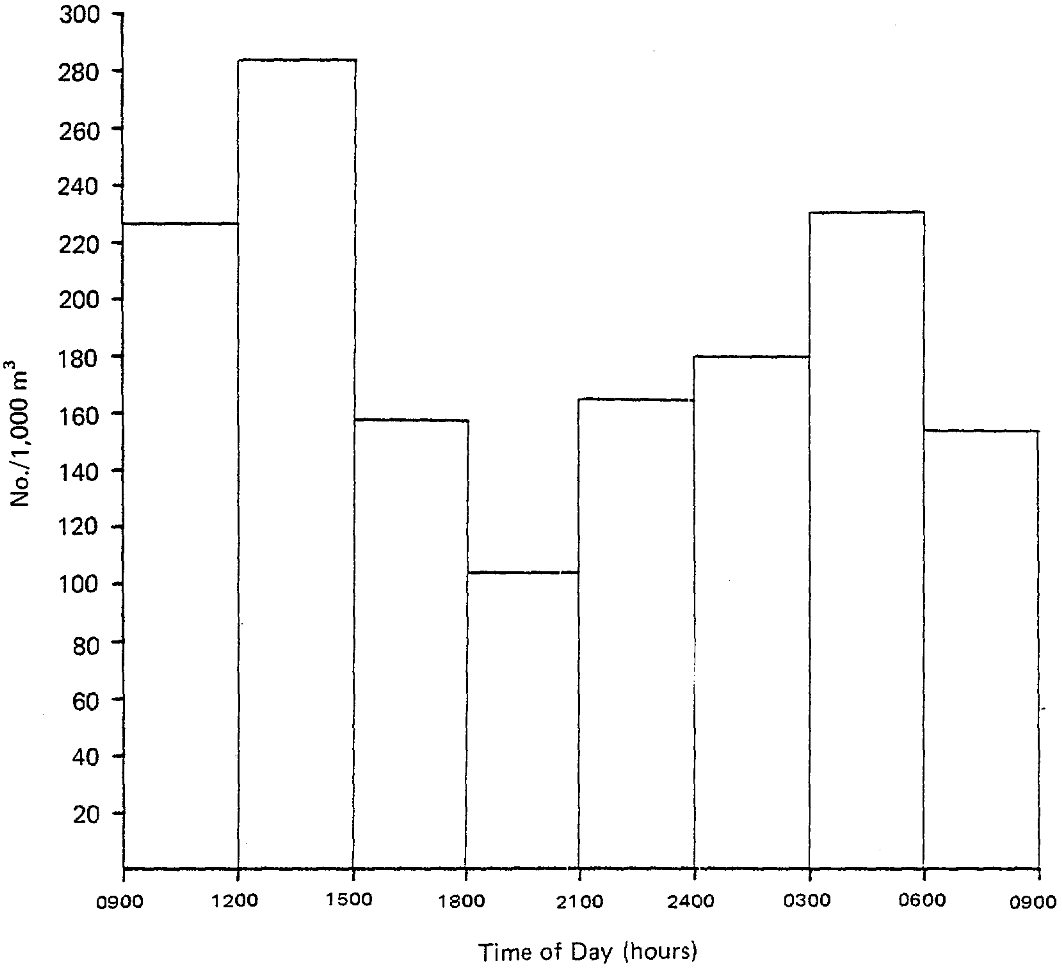
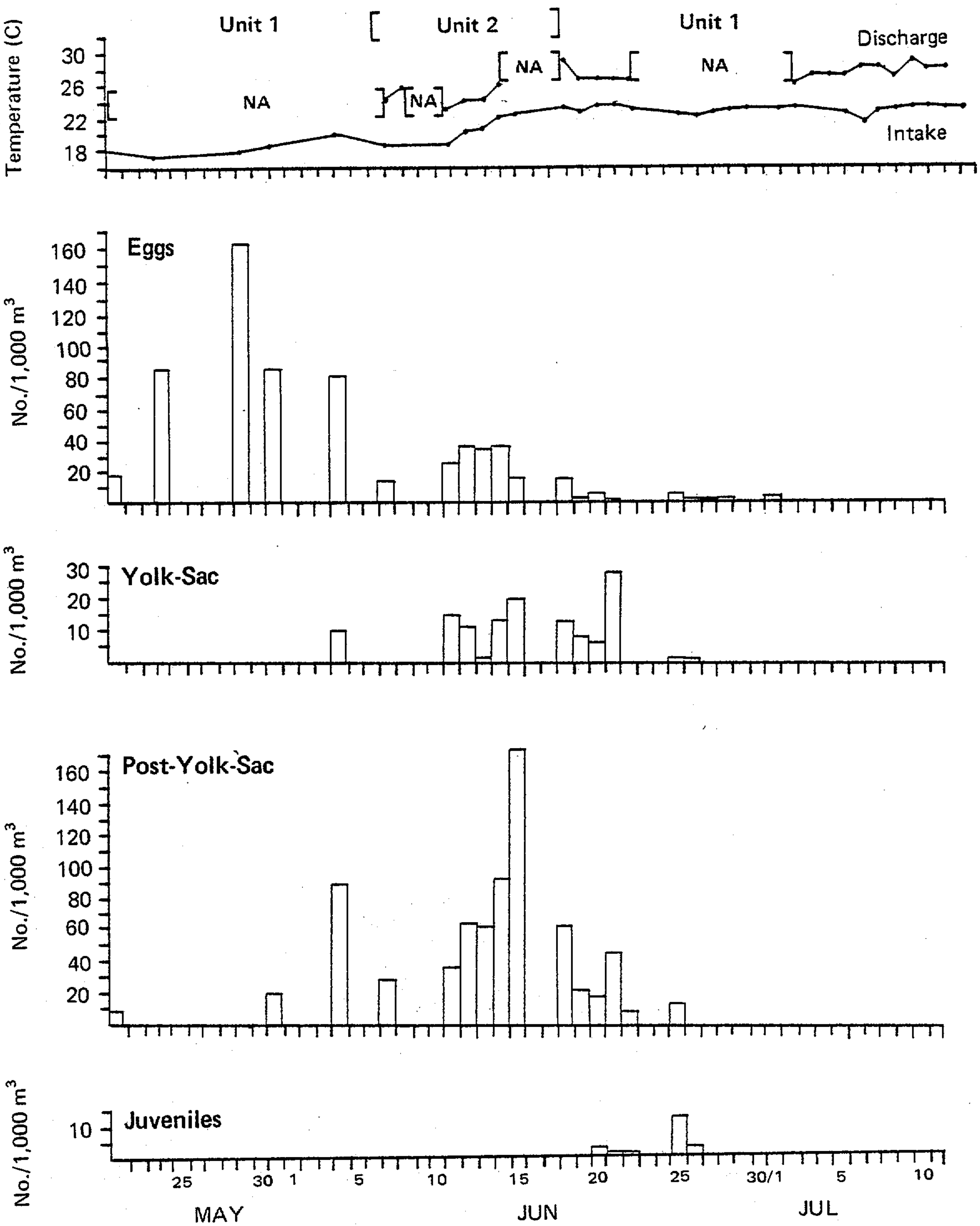
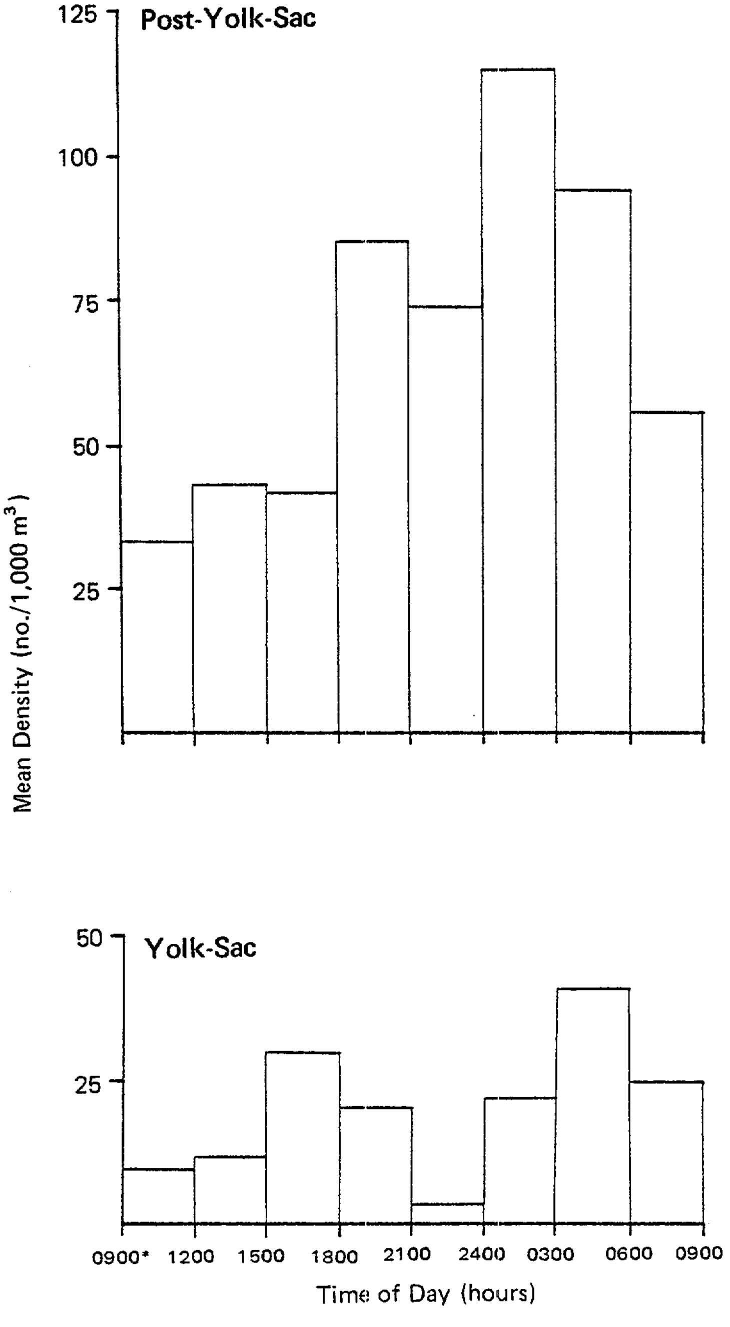


Figure 6-8. Diel distribution of Atlantic tomcod, all life stages combined, collected at the Bowline Point plant discharge, 1979.



NA – Unit offline; no discharge temperature available.

Figure 6-9. Seasonal distribution of white perch at the Bowline Point plant discharge during entrainment abundance studies, 1979.



* Indicates sample start time.

Figure 6-10. Diel distribution of white perch at the Bowline Point plant discharge during entrainment abundance studies, 1979.

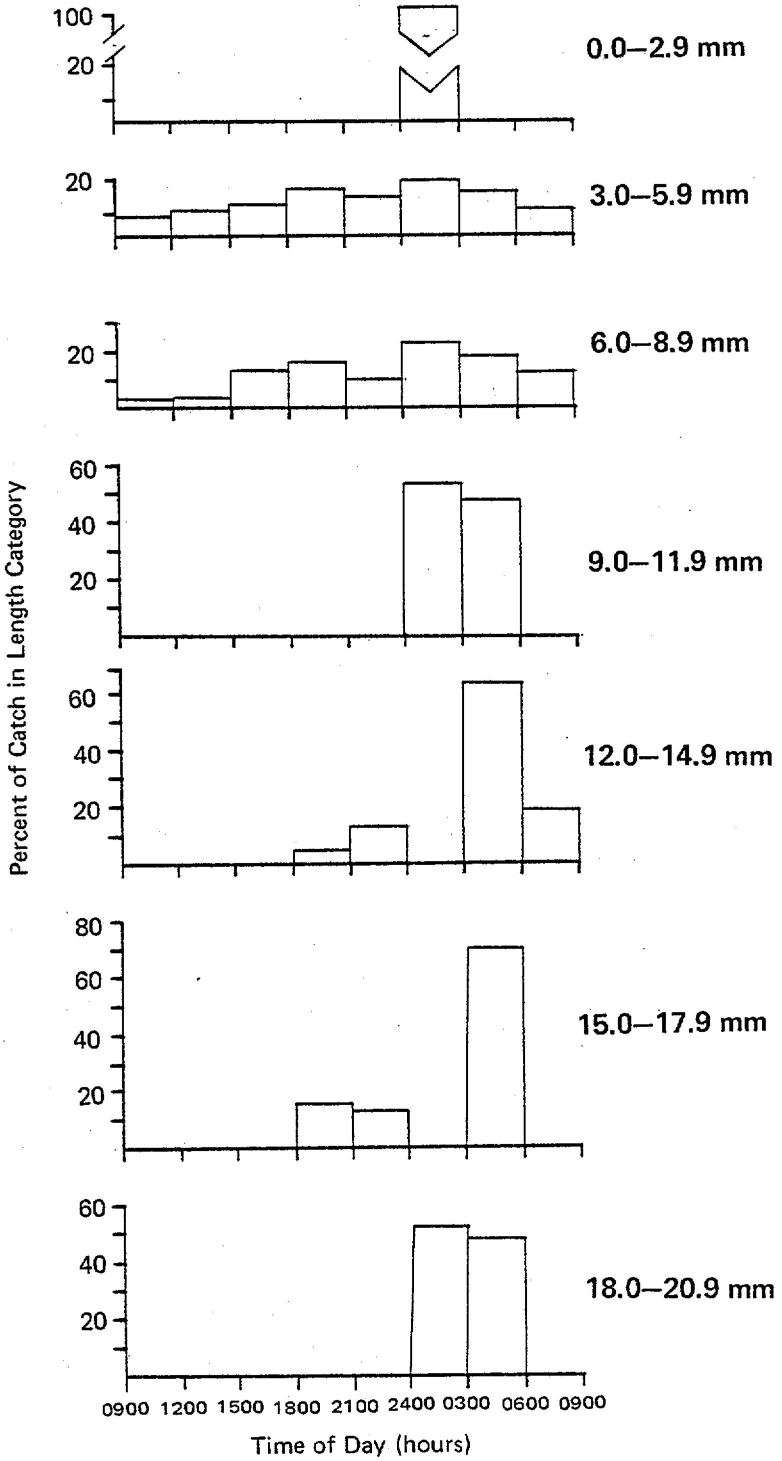
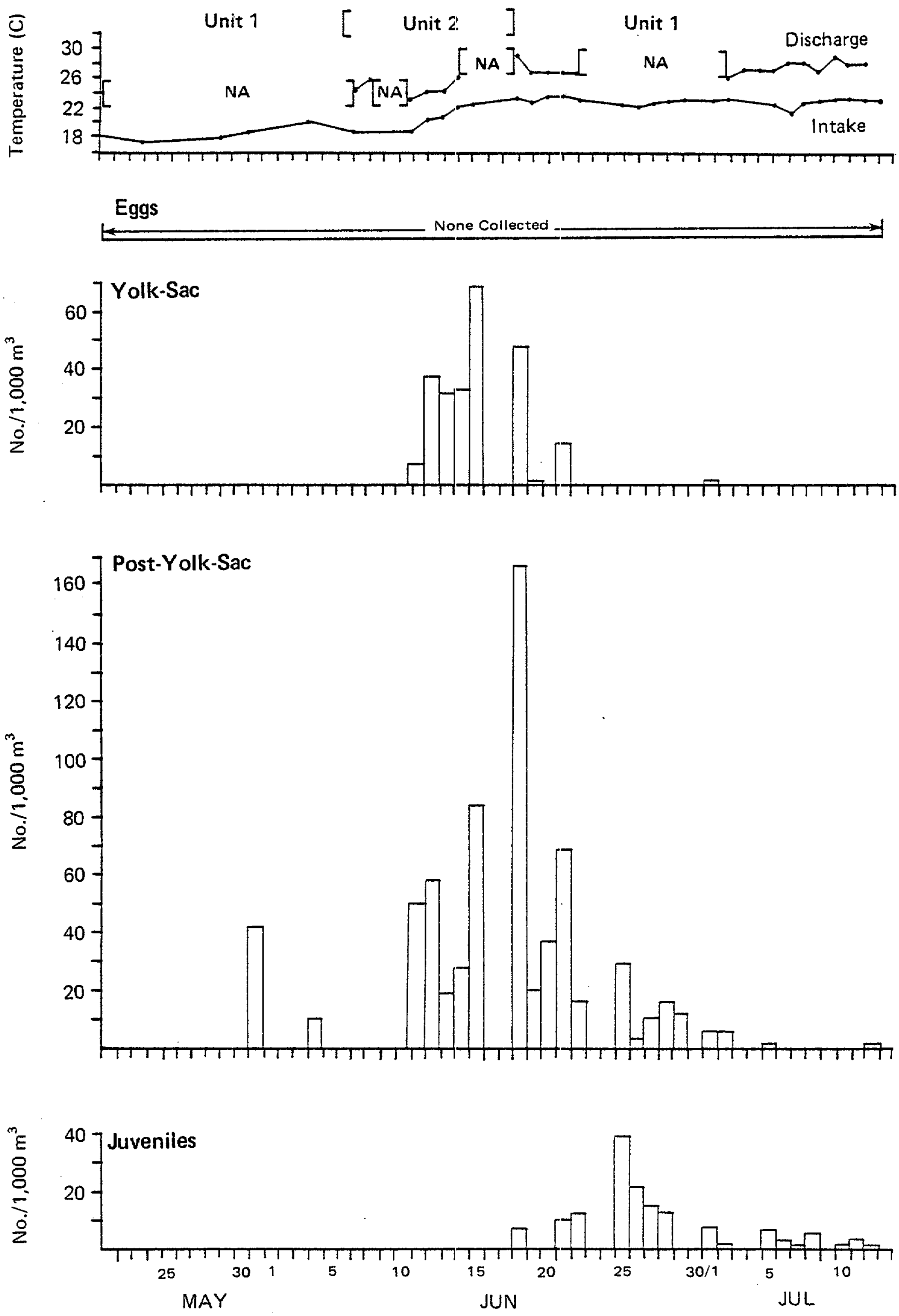


Figure 6-11. Mean diel length distribution for white perch collected at the Bowline Point plant discharge, 1979.



NA – Unit offline; no discharge temperature available.

Figure 6-12. Seasonal distribution of striped bass at the Bowline Point plant discharge during entrainment abundance studies, 1979.

in 1979 and may indicate that spawning and growth were earlier in 1978. In addition, river conductivity was lower in 1978 (less than 700 µmhos/cm) than 1979 (greater than 1,000 µmhos/cm), which may have resulted in differences in river distribution and relative abundance in the vicinity of the Bowline Point plant. Juveniles were collected from mid-June to early July with peak abundance that was two times higher than 1978 during the last week in June. Ambient water temperature and conductivity were similar when peak juvenile abundance occurred in 1977, 1978, and 1979.

Striped bass collected during 1979 ranged from 5 to 34 mm in length. The length distribution was similar to 1977 and 1978, with 31 percent of all striped bass between 6 and 9 mm (Figure 6-4, Table F-4).

Striped bass were most abundant at night. Peak yolk-sac, post yolk-sac, and juvenile abundance occurred between 2100 and 0600 hours (Figure 6-13, Table G-4). The diurnal distribution with peak collection at night becomes progressively more distinct with length (Figure 6-14). Larvae larger than 15 mm are collected almost exclusively between 2100 and 0600 hours.

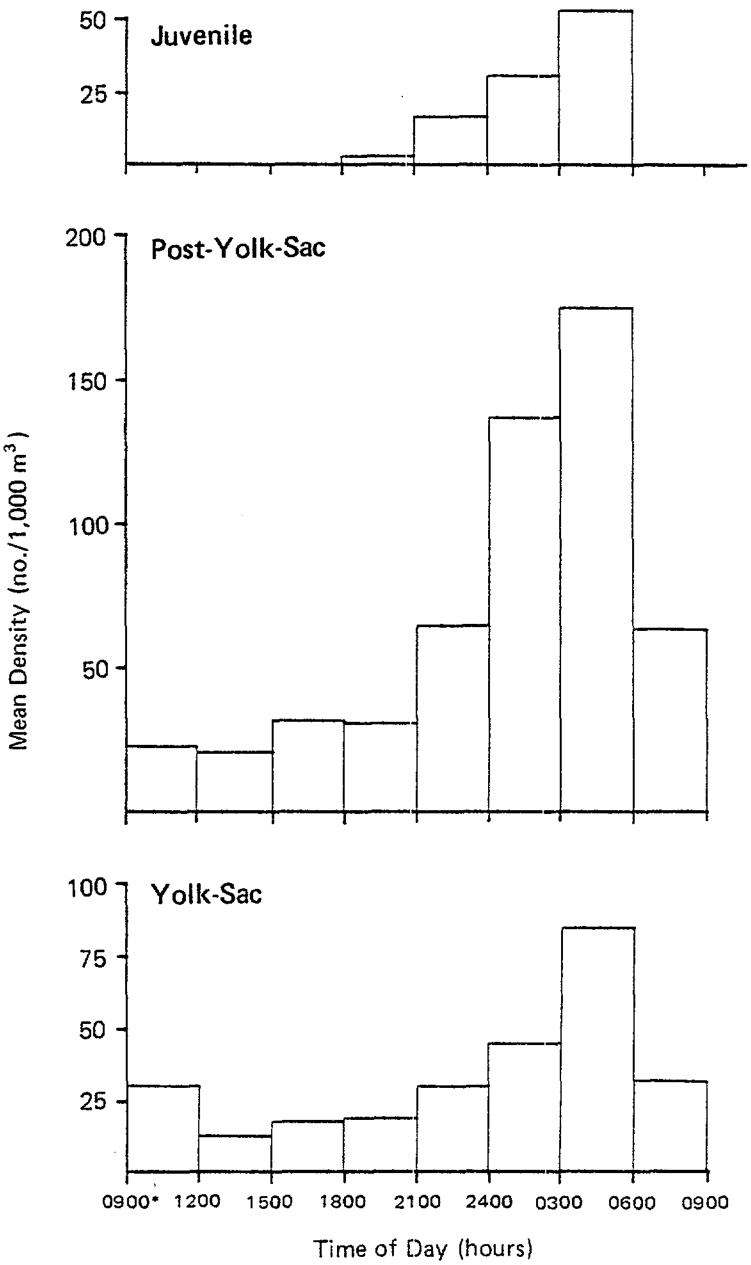
6.2.3.1.5 Clupeids

Clupeids (alewife, blueback herring, and American shad) spawn primarily in the freshwater portion of the river north of Bowline Point. Spawning of these three clupeids overlaps temporarily and ranges from April through June. American shad were rarely collected (less than 1 percent of the total abundance) during abundance sampling. In 1978, eggs and larvae were most abundant in entrainment samples from mid-May through late June; however, during 1979, eggs and yolk-sac larvae were not collected possibly because of the limited sampling effort while the plant was offline. Abundance of post yolk-sac larvae was very low in 1979, with a peak observed during the second week of June when ambient temperatures reached 18-20 C (Figure 6-15, Table E-5). Clupeid larvae collected ranged from 4 to 28 mm in length. Larvae from 6 to 9 mm constituted 35 percent of the clupeids collected at the discharge (Figure 6-4, Table F-5). Clupeid juveniles were not collected during the season; Clupeid post yolk-sac larvae exhibited a variable diel pattern with peak abundance between 1800 and 2100 hours (Figure 6-16, Table G-5). The apparent difference between the bimodal 1978 and 1979 diel distribution is probably an artifact of the low abundance and limited sampling schedule in 1979.

6.2.3.2 1979 Intake Sampling

Entrainment abundance and species composition were determined from 30-minute net samples at the surface, middle, and bottom depths at the Bowline Point plant intake. Samples were collected once per week during peak Atlantic tomcod season and twice per week during peak *Morone* spp. occurrence. Bay anchovy larvae accounted for 66.1 percent of all ichthyoplankton collected (Table 6-6). The next four most abundant taxa were white perch, striped bass, Atlantic tomcod, and clupeids. Clupeid abundance was too low to draw any conclusions about distribution and will not be addressed further.

Bay anchovy larvae were collected from 11 June - 9 July when all intake sampling stopped. Larval abundance gradually increased throughout the sampling season with peak densities of 1,003 per 1,000 m^3 observed on the last sampling



* Indicates sample start time.

Figure 6-13. Diel distribution of striped bass at the Bowline Point plant discharge during entrainment abundance studies, 1979.

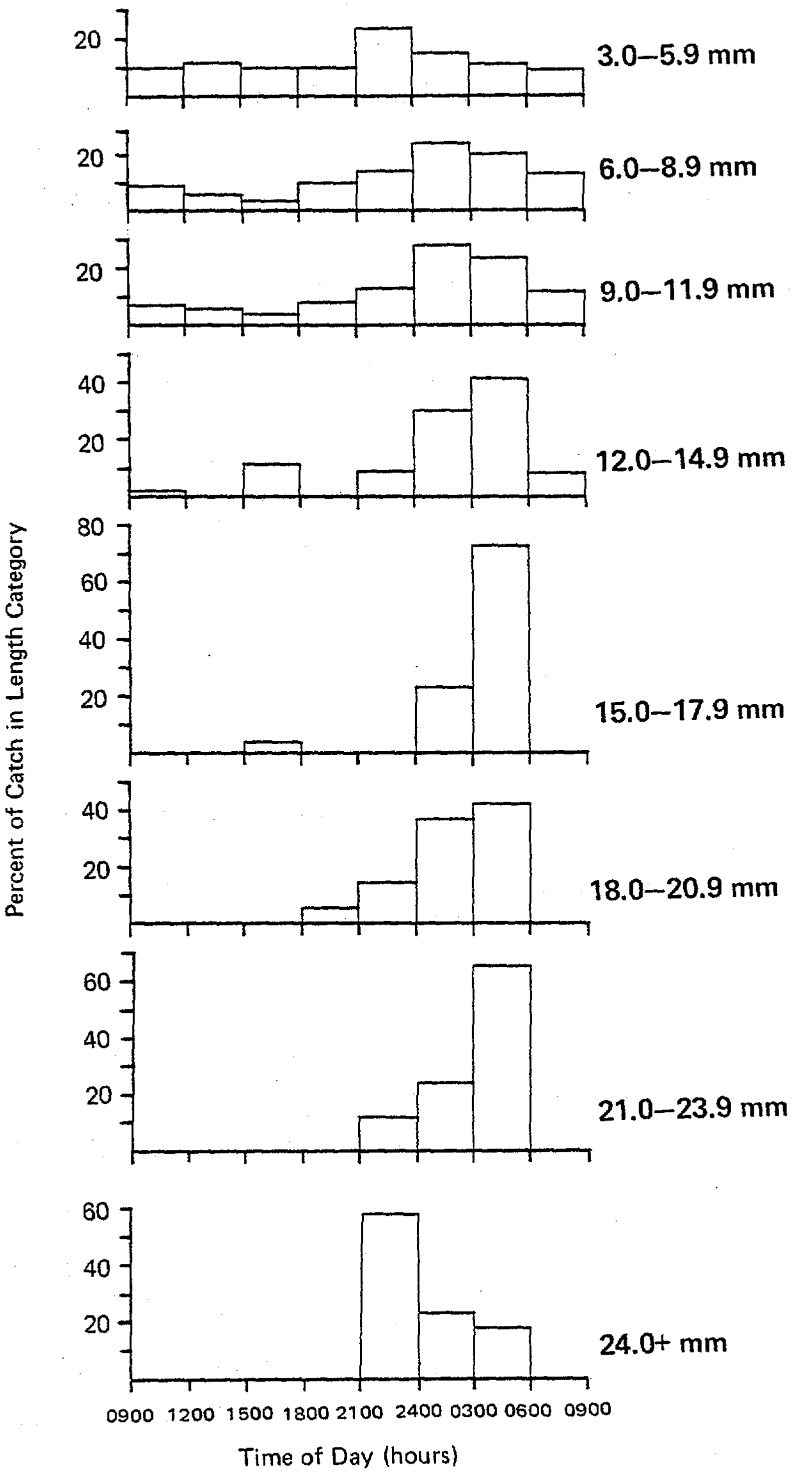
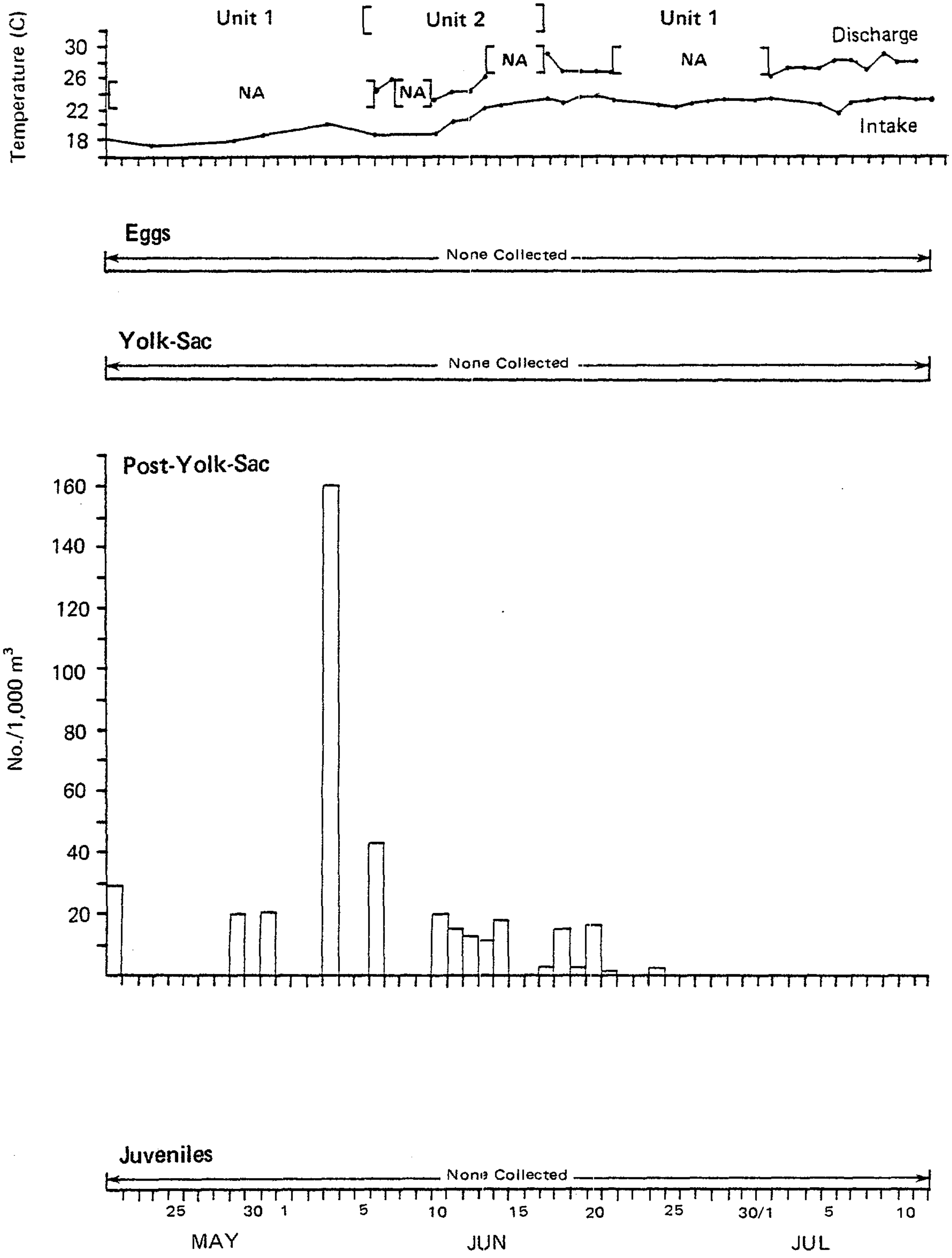
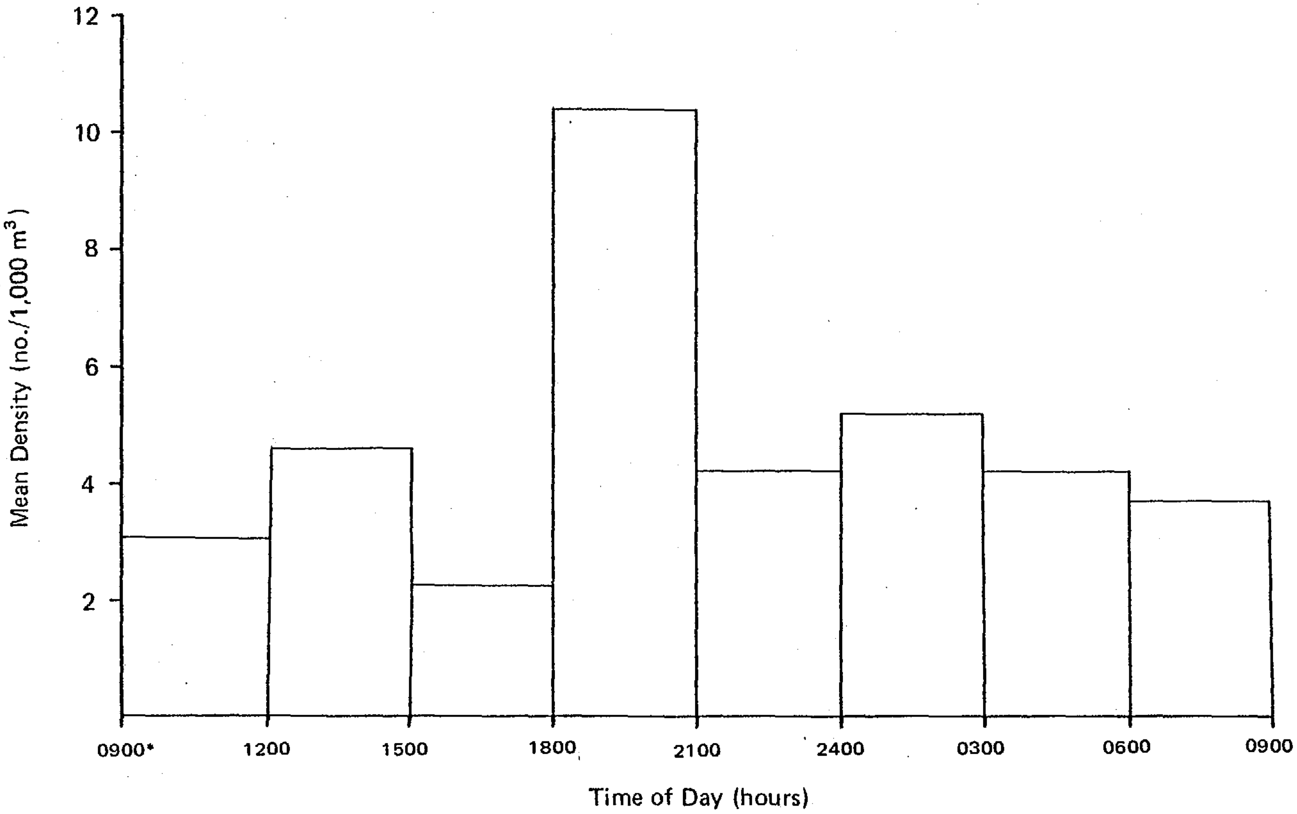


Figure 6-14. Mean diel length distribution for striped bass collected at the Bowline Point plant discharge, 1979.



NA — Unit offline; no discharge temperature available.

Figure 6-15. Seasonal distribution of Clupeidae at the Bowline Point plant discharge during entrainment abundance studies, 1979.



* Indicates sample start time.

Figure 6-16. Diel distribution of Clupeid post-yolk-sac larvae collected at the Bowline Point plant discharge, 1979.

TABLE 6-6 NUMBER AND PERCENT COMPOSITION BY TAXA AND LIFE STAGE OF ORGANISMS ENTRAINED AT THE BOWLINE POINT PLANT INTAKE, 1979

Species	Eggs	YSL	PYSL	JUV	UID	Total	%
Bay anchovy	1	8	979			988	66.7
Atlantic tomcod		134	15		32	181	12.2
White perch		5	143	3		151	10.2
Striped bass		11	67	3		81	5.5
Clupeid			27			27	1.8
Minnow	17	3				20	1.3
Silverside			12			12	0.8
Unidentifiable specimen	1				9	10	0.7
Morone spp.			5		1	6	0.4
Sunfish			2			2	0.1
Tessellated darter		1				1	0.1
American eel				1		1	0.1
Rainbow smelt			1			1	0.1
Total	19	162	1,251	7	42	1,481	
Percent	1.3	10.9	84.5	0.5	2.8		

night, 9 July (Figure 6-17, Table H-1). More larvae were consistently collected at night than during the day. The density of larvae collected at the intake was not significantly different ($t = 1.7046$, d.f. = 7, $\alpha = 0.05$) from that observed at the discharge when both stations were sampled on the same day. The average volume sampled at the intake and discharge during these periods was 448 m^3 and 561 m^3, respectively. Over 55 percent of the bay anchovy collected were between 3-9 mm, and the rest were evenly distributed from 9 to 21 mm (Figure 6-18, Table I-1). This distribution was similar to that observed for pumped samples at the discharge (Figure 6-4).

White perch were collected from 21 May - 5 July with maximum larval abundance observed on the night of 14 June (Figure 6-19, Table H-2). Larvae measuring 3-5 mm constituted 36 percent of all white perch larvae collected (Figure 6-18). White perch were most abundant at night, and no larvae larger than 12 mm were collected during the day (Figure 6-20, Table I-2). All length classes were most abundant at the bottom or middepths; only the 3-6 mm range were found at all depths during both day and night.

Comparison of the intake and discharge samples indicated no significant difference ($t = 1.9645$, d.f. = 5, $\alpha = 0.05$) in densities of white perch collected. Furthermore, the length frequency distribution was also similar between the two stations, although more larvae were collected at the discharge between 3-6 mm.

Striped bass were collected from 29 June to 2 July with peak abundance on the night of 14 June (Figure 6-21, Table H-3). Larvae from 6.0 to 8.9 mm constituted 72 percent of all striped bass collected at the intake (Figure 6-18). As length increased through the season, larvae became less abundant in surface and middle depths (Figure 6-22, Table I-3). Nearly all the striped bass were collected at night; those collected during the day were observed at the bottom only.

As with white perch and bay anchovy no significant differences were observed between the intake and discharge densities of striped bass ($t = 0.2958$, d.f. = 5, $\alpha = 0.05$). No larvae over 18 mm were collected with the intake nets, whereas approximately 15 percent of the larvae collected at the discharge exceeded 18 mm.

Atlantic tomcod were collected from 6 March to 27 March, the last sampling day for tomcod (Figure 6-23, Table H-4). Tomcod yolk-sac larvae abundance peaked on 27 March at 158 per 1,000 m^3; post yolk-sac larvae peaked the same night at 34 per 1,000 m^3. All tomcod collected were between 6.0-8.9 mm (Figure 6-18). Tomcod were evenly distributed over depth during the day (Figure 6-24, Table I-4); however, at night the bottom depth had lower abundance than the surface and middle depths. In addition, Atlantic tomcod was the only species collected during the day at the intake with densities similar to night collections (Figure 6-23). This observation is consistent with the diel pattern at the discharge; discharge densities for the diel periods most closely associated with intake samples (1500 and 2100 hours) were also similar (Figure 6-8). Again, no significant differences in average daily density were observed between the intake and discharge ($t = 0.5907$, d.f. = 3, $\alpha = 0.05$), and the length distribution was the same for both stations.

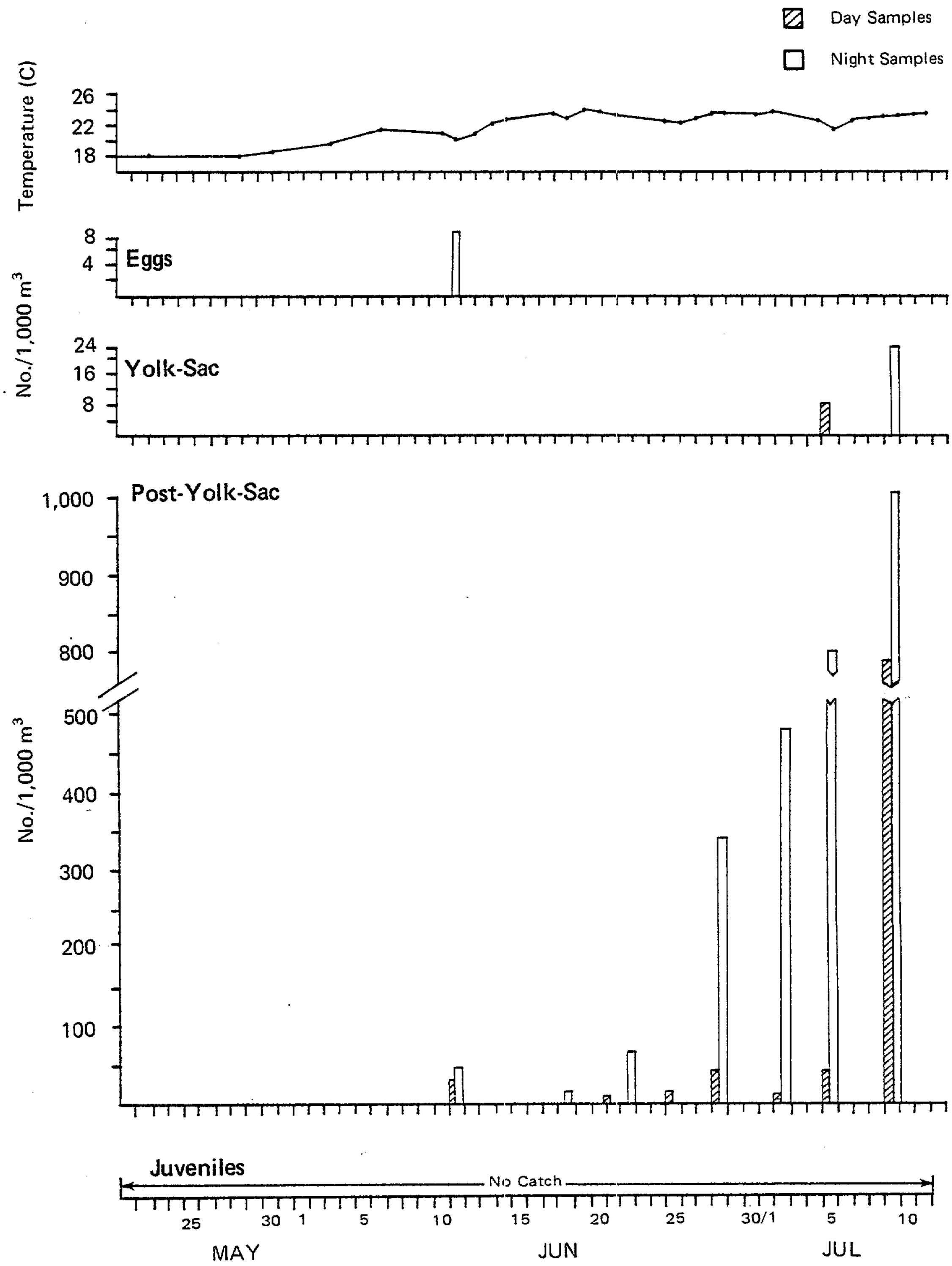


Figure 6-17. Seasonal distribution of bay anchovy at the Bowline Point plant intake during entrainment abundance studies, 1979.

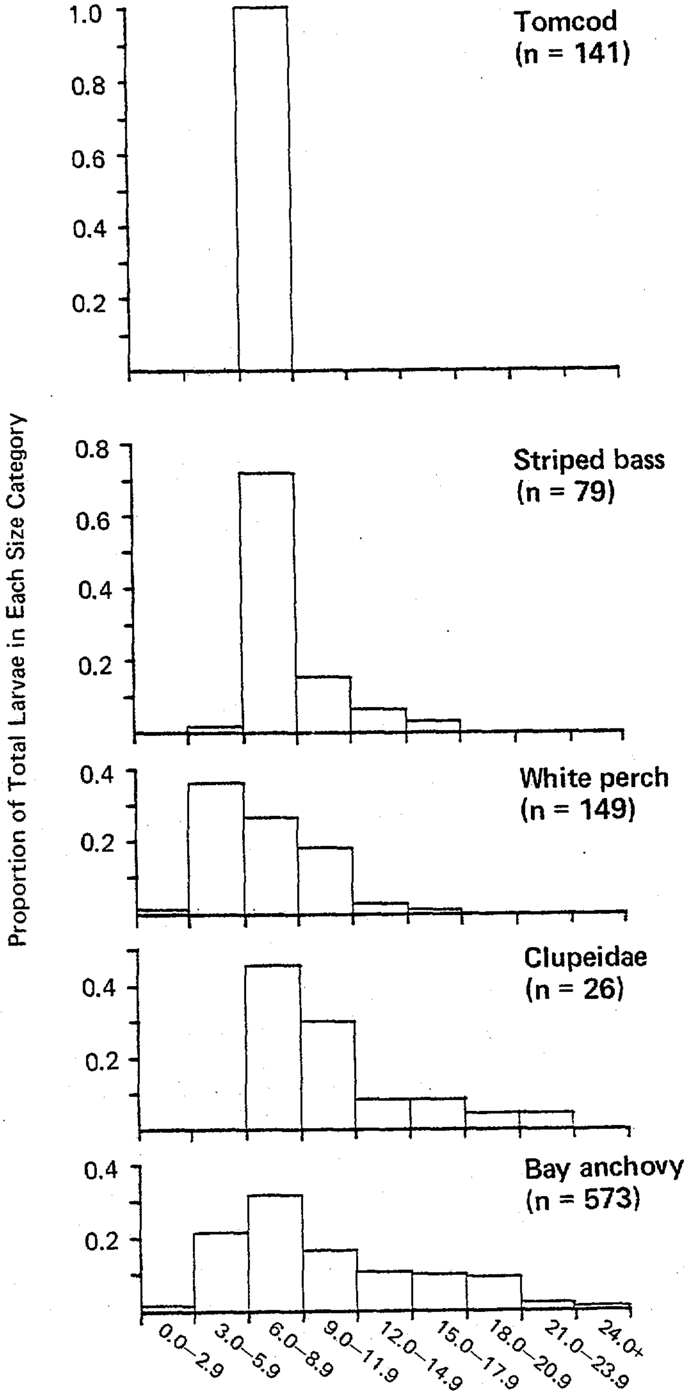


Figure 6-18. Length-frequency distribution of fish larvae collected at the Bowline Point plant intake, 1979.

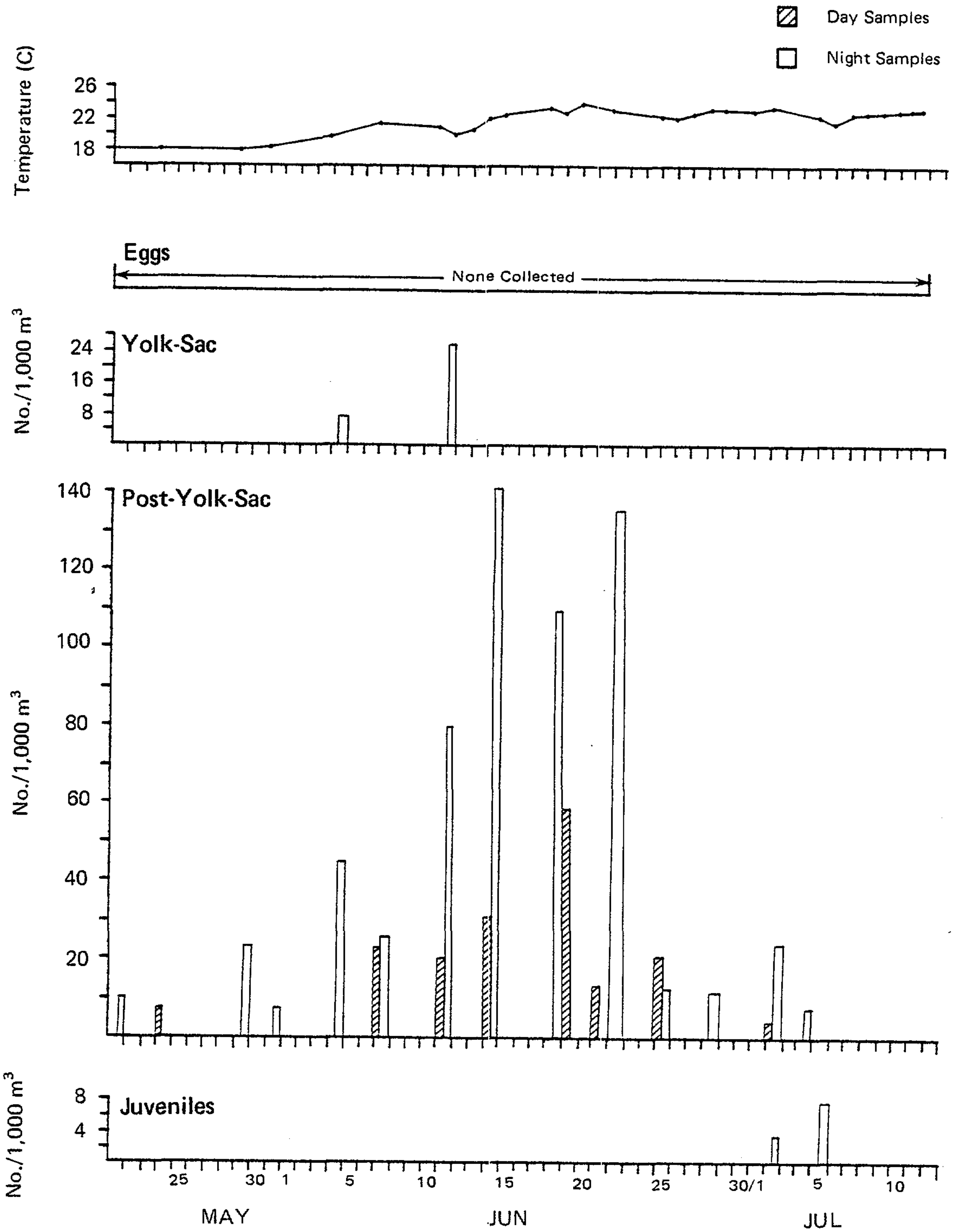


Figure 6-19. Seasonal distribution of white perch at the Bowline Point plant intake during entrainment abundance studies, 1979.

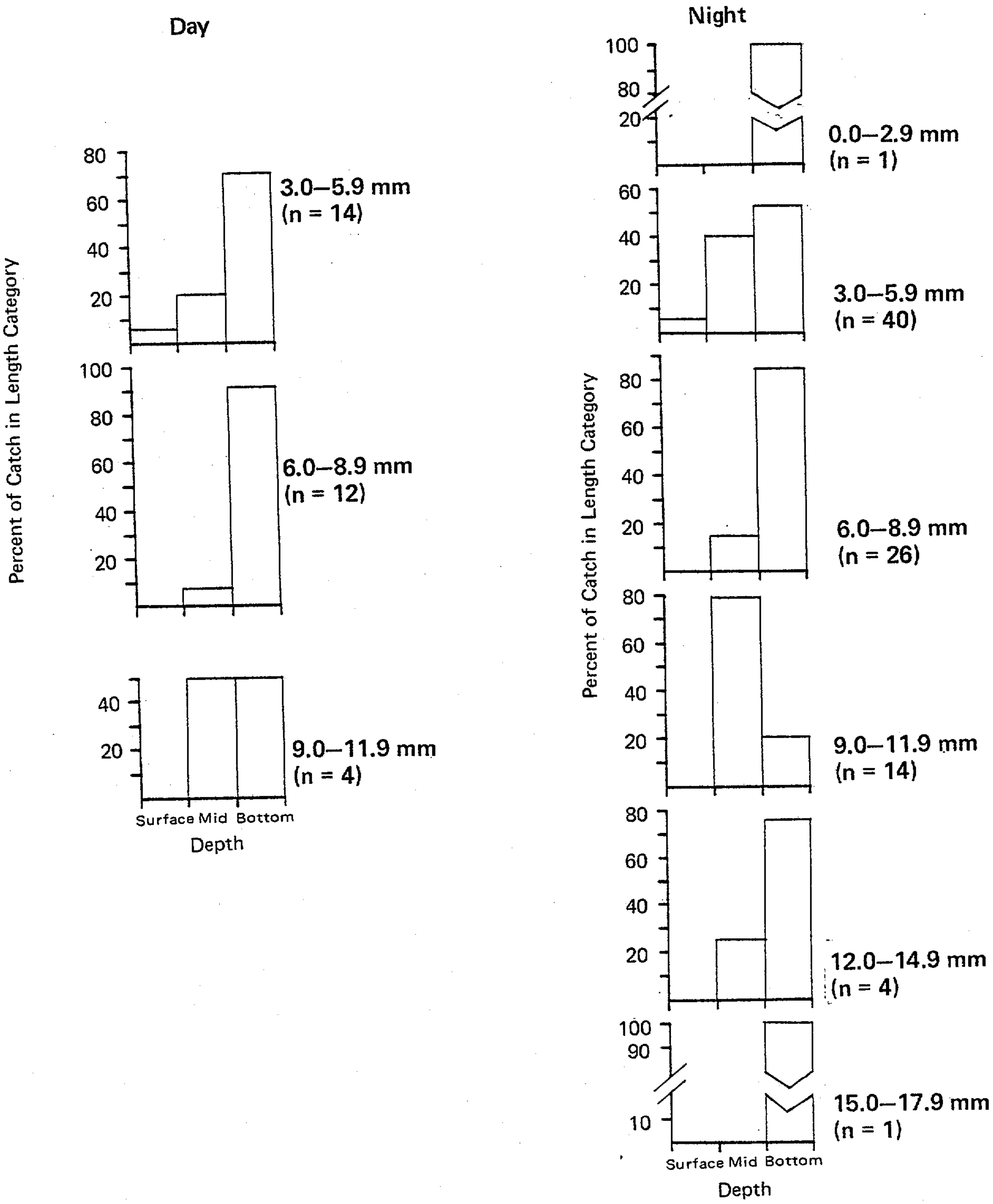


Figure 6-20. Depth-frequency distributions of white perch collected day or night by length class at the Bowline Point plant intake, 1979.

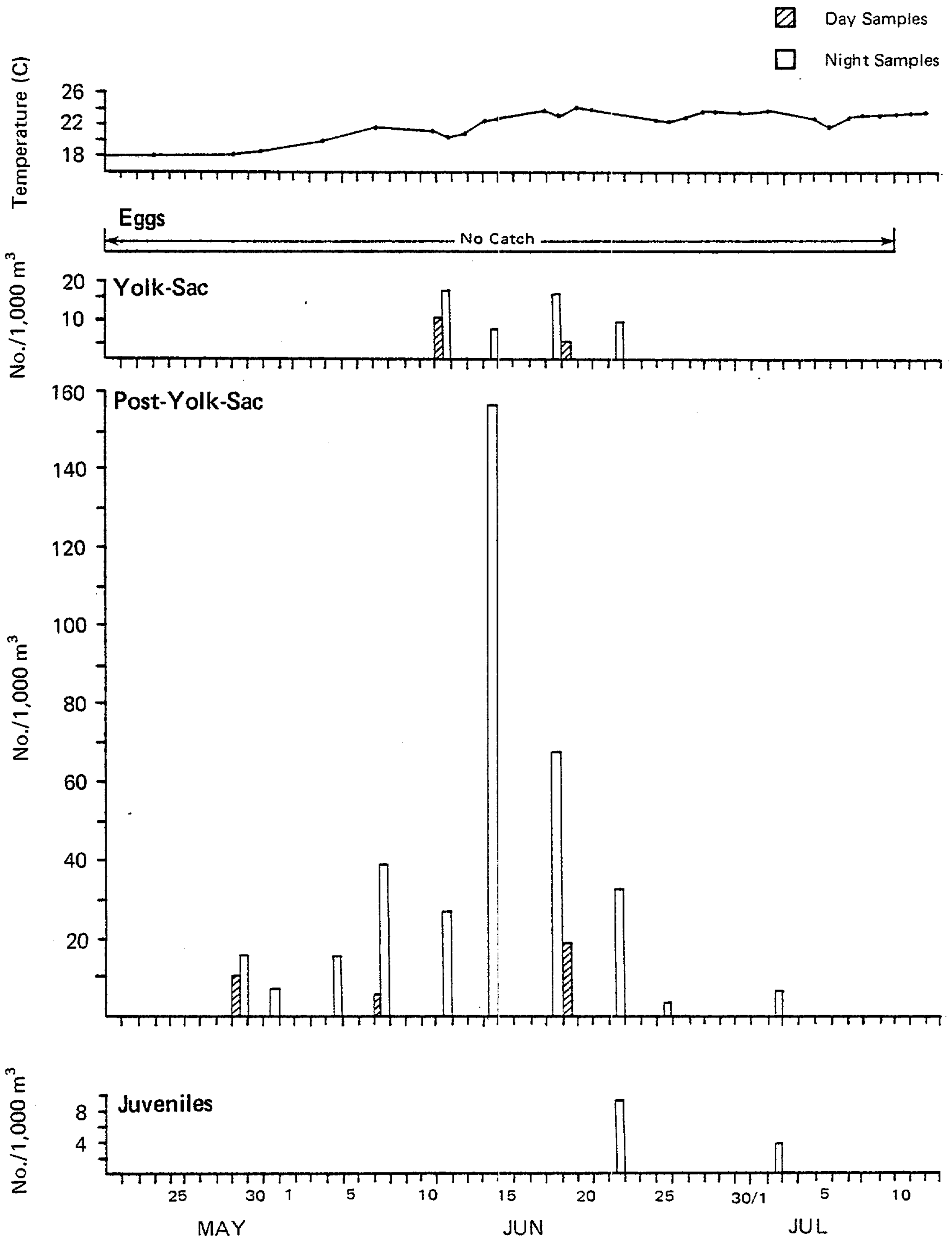


Figure 6-21. Seasonal distribution of striped bass at the Bowline Point plant intake during entrainment abundance studies, 1979.

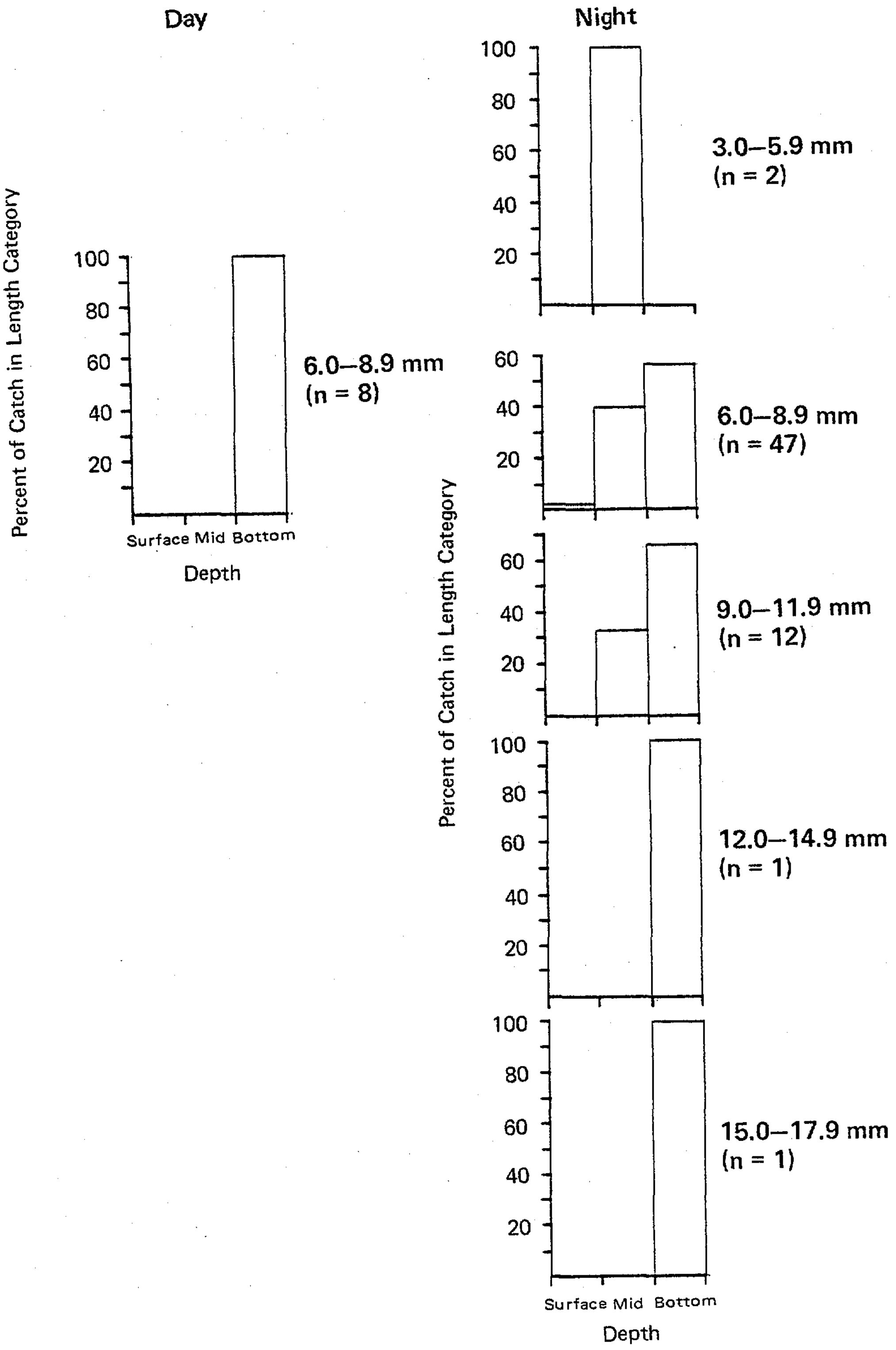


Figure 6-22. Depth-frequency distributions of striped bass collected day or night by length class at the Bowline Point plant intake, 1979.

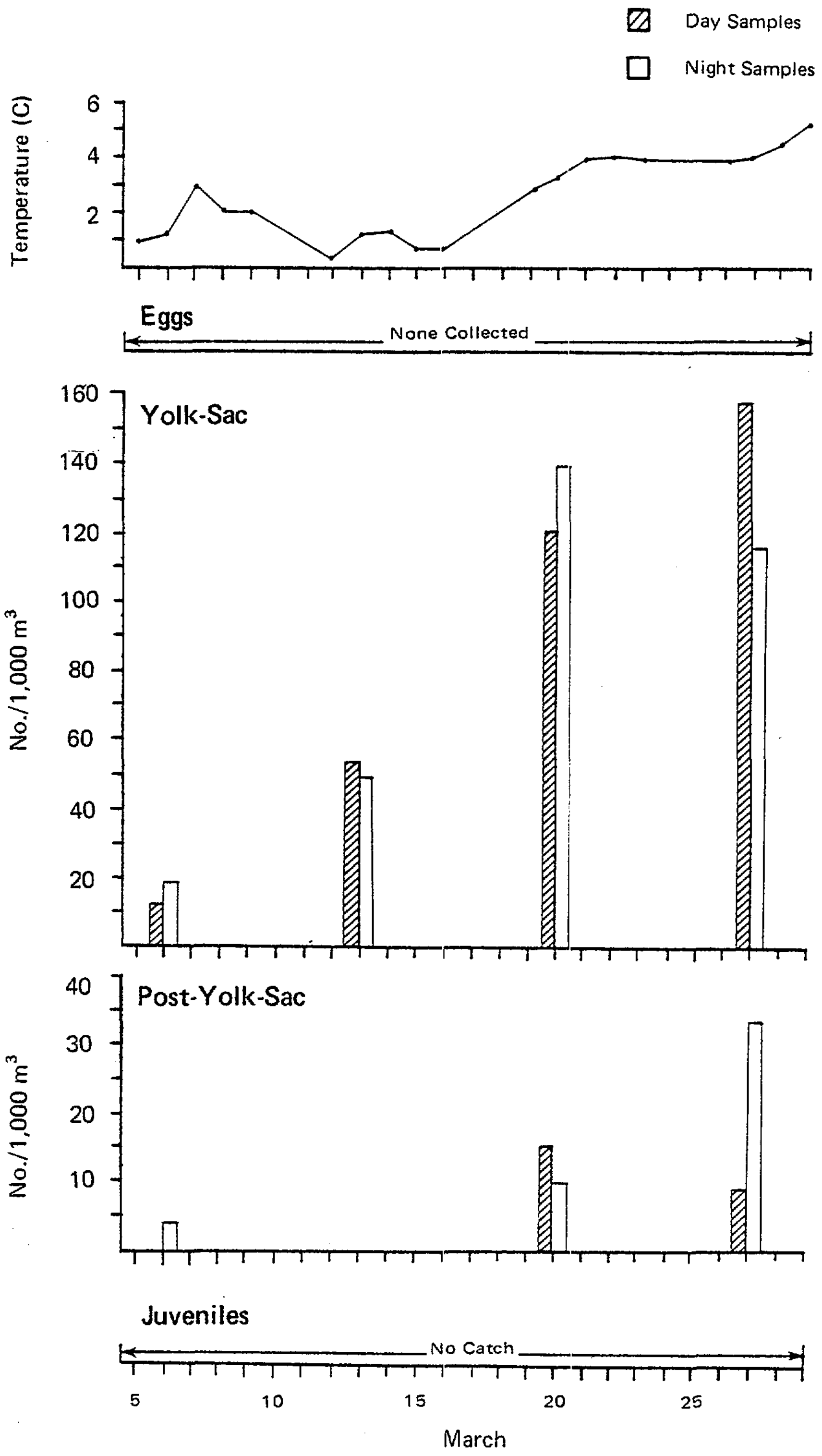


Figure 6-23. Seasonal distribution of Atlantic tomcod at the Bowline Point plant intake during entrainment abundance studies, 1979.

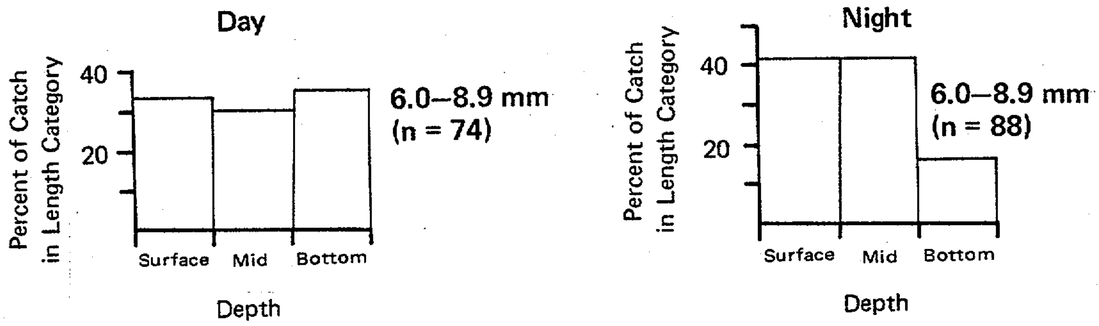


Figure 6-24. Depth-frequency distributions of Atlantic tomcod collected day or night by length class at the Bowline Point plant intake, 1979.

6.2.3.3 Entrainment Abundance Monitoring - 1975-1979 Overview

Between 1976 and 1979 entrainment abundance was monitored at the Bowline Point plant using nets and pumps; during 1975 only plankton nets were used. Special studies were conducted during 1975 (EA 1976) to determine the optimal sampling duration with the 0.5 m, 505-μm mesh plankton nets (R~7) which would provide the largest sample volume but minimize the likelihood of net clogging. The volume of water sampled with no significant ($\alpha = 0.05$) clogging ranged from 40 to 100 m^3 depending on net location (surface vs. bottom) and season (May vs. July). In a related conclusion, EA (1976) found that at intake velocities of 15-25 cm/sec. clogging of the net did not affect total sample volume for durations up to 30 minutes. As intake velocities at the Bowline Point plant do not exceed this range, sampling durations subsequent to 1975 were standardized at 30 minutes. However, durations were occasionally reduced if flowmeter records or detrital and algae densities indicated a potential for clogging.

During 1976 an experimental three-depth pumped sampler was tested at the Bowline intake as a potential alternative to sampling with plankton nets (EA 1977b). Densities and seasonal distribution from both gear were similar during striped bass, white perch, and clupeid entrainment seasons (late May through June). However, more larger organisms were collected by the pump system. Although juvenile striped bass and white perch were collected by the pumps, none were collected in the nets. In contrast, bay anchovy abundance was higher in the nets than the pump, but the size range of organisms was similar for both years. Density varied with depth in the net samples; therefore, if disproportionate volumes were sampled from each depth by the two gear, densities and length frequencies for depth-composited samples may vary considerably between the nets and pump.

Densities of the major taxa were generally comparable between the discharge and intake in 1977 and 1979. One major discrepancy between stations occurred for white perch eggs that were collected at the discharge in densities up to 113 and 161 per 1,000 m^3 during 1977 and 1979, respectively, but none were collected at the intake. This difference is probably the result of patchiness or stratification of eggs at the intake which is eliminated by mixing in the plant cooling system. Furthermore, although juvenile densities for the most abundant taxa were relatively low compared to other life stages, abundance at the discharge was much higher than at the intake. The maximum juvenile density for these two years was 9 per 1,000 m^3 at the discharge. Avoidance of the intake nets or patchy distribution may account for this difference. During 1978 peak densities were coincident at the intake and discharge; however, densities at the discharge were approximately 1.5 (white perch) to 8 (striped bass) times those observed at the intake. These comparisons of intake and discharge sampling indicate that the intake nets can generally provide data comparable to the discharge pumps. However, samples collected by pump at the discharge may provide a consistently more accurate estimate of entrainment abundance at the Bowline Point plant particularly for both life stages (i.e., juveniles). This is true because at the discharge the effects of ichthyoplankton patchiness and stratification may be reduced by mixing, and the potential for avoidance may be lower as a result of decreased light, visual cues, and approach velocity (tow speed) of the gear. In addition, the pumped sampler provides a more accurate measure of volume and eliminates the potential for clogging.

The species composition of entrainment abundance samples was similar from 1975 to 1979 at the Bowline Point plant (Table 6-7). Bay anchovy, Atlantic tomcod, white perch, striped bass, and clupeids generally comprised more than 85 percent of all organisms in each year. Differences between years primarily reflect differences in sampling frequency, duration, and organism distribution patterns related to riverwater chemistry. For example, during 1979, bay anchovy accounted for only 57.3 percent of the total catch because abundance sampling was terminated during the early part of bay anchovy season (early July); whereas sampling continued to the end of August between 1975 and 1978 when bay anchovy abundance exceeded 70 percent of the total catch.

Abundance of larval Atlantic tomcod in entrainment collections varies with conductivity. From 1975 to 1978, peaks in post yolk-sac abundance coincided with increases in river conductivity near Bowline (EA 1976, 1977b, 1978d, 1979a). During 1975, 1976, and 1978 conductivity fluctuated during March and April and post yolk-sac larvae exhibited multiple peaks. During 1976, 1977, and 1979 peak concentrations of yolk-sac larvae occured during periods of lowest conductivity. This pattern is consistent with differences in river-wide distributions of yolk-sac and post yolk-sac larvae Atlantic tomcod. Generally, yolk-sac larvae are most abundant in areas of freshwater or very low conductivity north of Bowline Point, and post yolk-sac larvae are most abundant in the lowest portion of the estuary where conductivity exceeds 100 µmhos/cm (EA 1978a).

Bay anchovy larvae are collected only during the summer when conductivity is high (in excess of 5,000 µmhos/cm) and relatively stable. Generally, conductivity increases during late June or early July. However, during 1975 and 1979 when conductivity approached 4,000 µmhos/cm for a short period in mid-June, some eggs and larvae were collected; after conductivity decreased, no bay anchovy were collected until conductivity increased again in mid-July.

Abundance of striped bass, white perch, and clupeids in entrainment samples showed no clear relationship with conductivity; however, river temperature did appear to influence the temporal distribution of the peak. The optimal river temperature range for peak spawning and river-wide abundance are (TI 1980a):

Life Stage	Temperature
Eggs	15-17 C
Yolk-sac	16.4-19.9 C
Post yolk-sac	18.6-21.5 C

Abundance of the life stages entrained at the Bowline Point plant is generally consistent with these optimal river temperature ranges. During 1978, 1977, and 1975, intake temperatures reached 15 C during mid-May; peak yolk-sac larval abundance at Bowline occurred about 2 weeks later at approximately 20 C (Table 6-8). Post yolk-sac entrainment was highest about 2 weeks after peak yolk-sac abundance in mid-June at about 22 C during 1979, 1978, and 1975. In 1977 the river temperature increased rapidly during mid-May and reached 20 C by 20 May. Similarly, post yolk-sac abundance occurred during the first week of June (one week earlier than 1979, 1978, and 1975) at about 22 C. In 1976, the river temperature at Bowline Point began to increase earlier and reached 15 C on 8 May, accompanied by a peak in yolk-sac abun-

TABLE 6-7 NUMBER OF ORGANISMS AND PERCENT OF ANNUAL COLLECTION FOR THE MOST ABUNDANT TAXA COLLECTED DURING ENTRAINMENT ABUNDANCE STUDIES AT THE BOWLINE POINT PLANT

	Percent of Annual Catch									
	1979		1978		1977		1976(a)		1975(a)	
Bay anchovy	57.3	(5,224)(b)	70.8	(19,929)	70.8	(13,663)	73.4	(4,808)	86.9	(8,532)
Atlantic tomcod	13.6	(1,236)	3.3	(937)	12.7	(2,447)	8.7	(530)	9.8	(961)
White perch	6.0	(551)	5.6	(1,568)	3.4	(658)	8.1	(497)	1.0	(94)
Striped bass	6.0	(543)	4.6	(1,296)	4.8	(932)	1.6	(99)	0.4	(43)
Clupeids	1.1	(92)	3.4	(948)	1.7	(331)	1.4	(87)	0.4	(37)
	84.0		87.7		93.4		93.2		98.5	

(a) Data for 1975 and 1976 taken from intake net and pump sampling; 1977-1979 data taken from discharge pump sampling.

(b) Number in parentheses equals number of organisms collected.

TABLE 6-8 DATES OF PEAK STRIPED BASS AND WHITE PERCH ENTRAINMENT IN RELATION TO RIVER TEMPERATURE AT THE BOWLINE POINT PLANT, 1975-1979

		Date of Peak Abundance				First Date River Temp. Recorded	
Species	Year	EGG	YSL[a]	PYSL	JUV	15 C	20 C
Striped bass	1979	NC[b]	12-18 JUN	15-18 JUN	25-26 JUN	15 MAY	4 JUN
	1978	NC	3-10 JUN	14-20 JUN	25-30 JUN	20 MAY	31 MAY
	1977	NC	2-8 JUN	2-8 JUN	29-30 JUN	12 MAY	20 MAY
	1976	NC	11 MAY - 15 JUN	15 JUN - 13 JUL	13 JUL	8 MAY	14 JUN
	1975	NC	4 JUN	11-18 JUN	NC	15 MAY	28 MAY
White perch	1979	24 MAY - 4 JUN	15-21 JUN	12-18 JUN	25 JUN	15 MAY	4 JUN
	1978	22 MAY - 3 JUN	2-16 JUN	5-16 JUN	NC	20 MAY	31 MAY
	1977	16-23 MAY	23 MAY	2-5 JUN	29 JUN - 5 JUL	12 MAY	20 MAY
	1976	4-11, 25 MAY	8 JUN	1, 22-30 JUN	NC	8 MAY	14 JUN
	1975	NC	NC	11-18 JUN	18 JUN	15 MAY	28 MAY

(a) YSL = yolk-sac larvae; PYSL = post yolk-sac larvae; JUV = juvenile.
(b) NC = no catch.

dance on 11 May. However, a period of cold weather caused a decline in river temperatures during late May, and a second peak in yolk-sac larvae occurred at 21 C in mid-June. After the cold weather in May the river did not reach 20 C until 14 June, and the peak of post yolk-sac abundance was protracted from mid-June through mid-July. This delay during 1976 carried through to juvenile entrainment which peaked on 13 July, whereas in 1977 through 1979 the peak occurred during the last week of June. River-wide striped bass ichthyoplankton abundance also exhibited this bimodal peak during 1976, an apparent result of two major spawning periods (TI 1979).

White perch entrained at the Bowline Point plant exhibited a similar pattern with respect to river temperatures (Table 6-8). Clupeid abundance was highly variable throughout the spring of all five years and probably reflects life history differences between alewife and blueback herring which tend to mask environmental effects.

Diel trends in abundance were tested statistically with the Friedman rank sum test (Hollander and Wolfe 1973) for only the most abundant taxa-life stage combinations. To avoid loss of power for the test, sampling dates on which the organism was present in the sample in less than five of the collection periods were omitted from the test. The null hypothesis that densities in all collection periods are equal was tested against the alternative hypothesis that densities in all collection periods are not equal. Based on the Friedman rank sum test (Table 6-9) the differences in density among collection periods were significant for striped bass ($\alpha = 0.01$) and white perch post yolk-sac larvae ($\alpha = 0.05$). The most abundant taxa were generally collected in the highest densities between 2400 and 0900 hours, while lowest densities occurred between 0900 and 1500 during each year (Table 6-10). Some of the variability observed between years for the major taxa is related to annual differences in the relative proportions of each life stage (Atlantic tomcod) or species (Clupeids), and sample variability during years of low density or sampling effort (striped bass, 1977). When diel densities are averaged across years (1977 through 1979 discharge samples) the same trend is generally apparent (Figure 6-25). Striped bass and Atlantic tomcod exhibit the largest diel differences. The peak (48 to 59 percent of the total daily density) for post yolk-sac larvae of both species and yolk-sac striped bass occurs between 2400 and 0900. Tomcod yolk-sac larval density was lowest between 0300 and 1200 and exhibited a relatively even distribution at higher levels throughout the rest of the day. Yolk-sac white perch had a bimodal distribution with distinct peaks at 1500-1800 and 0300-0600 hours. Bay anchovy and white perch post yolk-sac exhibit no distinct peak but had minimun densities between 1200 and 1500. Clupeids had two minor peaks (1200-1500 and 2400-0600) which may reflect diel differences in the geographical (vertical or horizontal) distribution of alewife and blueback herring.

The diel pattern of entrainment is important when considered in conjunction with a diurnal-generation profile of the Bowline Point plant and ichthyoplankton survival of thermal stress. The generation profiles show that the plant typically operates at daily minimum levels of 20-30 percent of capacity in the early morning hours, and reaches maximum levels of 85-95 percent of capacity in mid-afternoon (EA 1978a). The day/night monthly plant capacity factors for the primary entrainment period indicate that between 2100 and 0600 the plant typically operates at less than 70 percent capacity (EA 1978a).

TABLE 6-9 RESULTS OF FRIEDMAN RANK SUM TEST FOR DIFFERENCES IN DENSITIES ACROSS COLLECTION PERIODS FOR THE MOST ABUNDANT TAXA COLLECTED AT THE BOWLINE POINT DISCHARGE, 1975-1979

Taxon	Life Stage(a)	n(b)	Rank Sum for Each Time Period								S^1(c)
			0900	1200	1500	1800	2100	2400	0300	0600	
Bay anchovy	PYSL	16	78.5	82	93	72	69.5	63.5	60	58	10.53
Striped bass	YSL	5	28	34	25.5	25	24.5	17	12	14	13.21
	PYSL	14	68.5	82	78	73	60	48	41	53.5	18.53**
White perch	YSL	5	29	21.5	18	25	25.5	21	14	26	5.66
	PYSL	14	69	91.5	64.5	50	64.5	59	57.5	48	15.50*
Atlantic tomcod	YSL	6	33	26	34	21	16	23.5	32.5	30	9.97
	PYSL	5	23	25	28	24	23.5	17	15	24.5	4.36
Clupeids	PYSL	7	43.5	28	34.5	35.5	26	24.5	26.5	30	7.78

(a) PYSL = post yolk-sac larvae; YSL = yolk-sac larvae.

(b) Number of sampling dates when organisms were collected in at least five of the eight collection periods.

(c) Test statistic (S^1) has an approximate chi-square (χ^2) distribution under the null hypothesis (i.e., densities during all collection periods are equal); critical value at $\alpha = 0.05$ is 14.1 and at $\alpha = 0.01$ is 18.5.

* Denotes $p \leq 0.05$

** Denotes $p \leq 0.01$

TABLE 6-10 SUMMARY OF DIEL ENTRAINMENT ABUNDANCE PATTERNS AT THE BOWLINE POINT PLANT, 1975-1979

	Time of Diel Peak				
Taxa	1979[(a)]	1978[(a)]	1977[(a)]	1976[(b)]	1975[(b)]
Striped bass	2400-0600	2100-0900	0900-1200	Night	Night-Dawn
White perch	2400-0600	None	1500-2400	Night	Night-Dusk
Atlantic tomcod	0300-0600 0900-1500	2400-0600	1800-2400	Night	Dawn
Bay anchovy	0600-1200 2100-2400	2400-0600	2400-0300	Night	Night-Dusk
Clupeids	1800-2100	1200-1500 2400-0300	2400-0600	None	Night-Dawn

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(a) Continuous 24-hour pumped abundance samples collected at the discharge.
(b) Intake net samples collected at noon, dusk, midnight, and dawn.

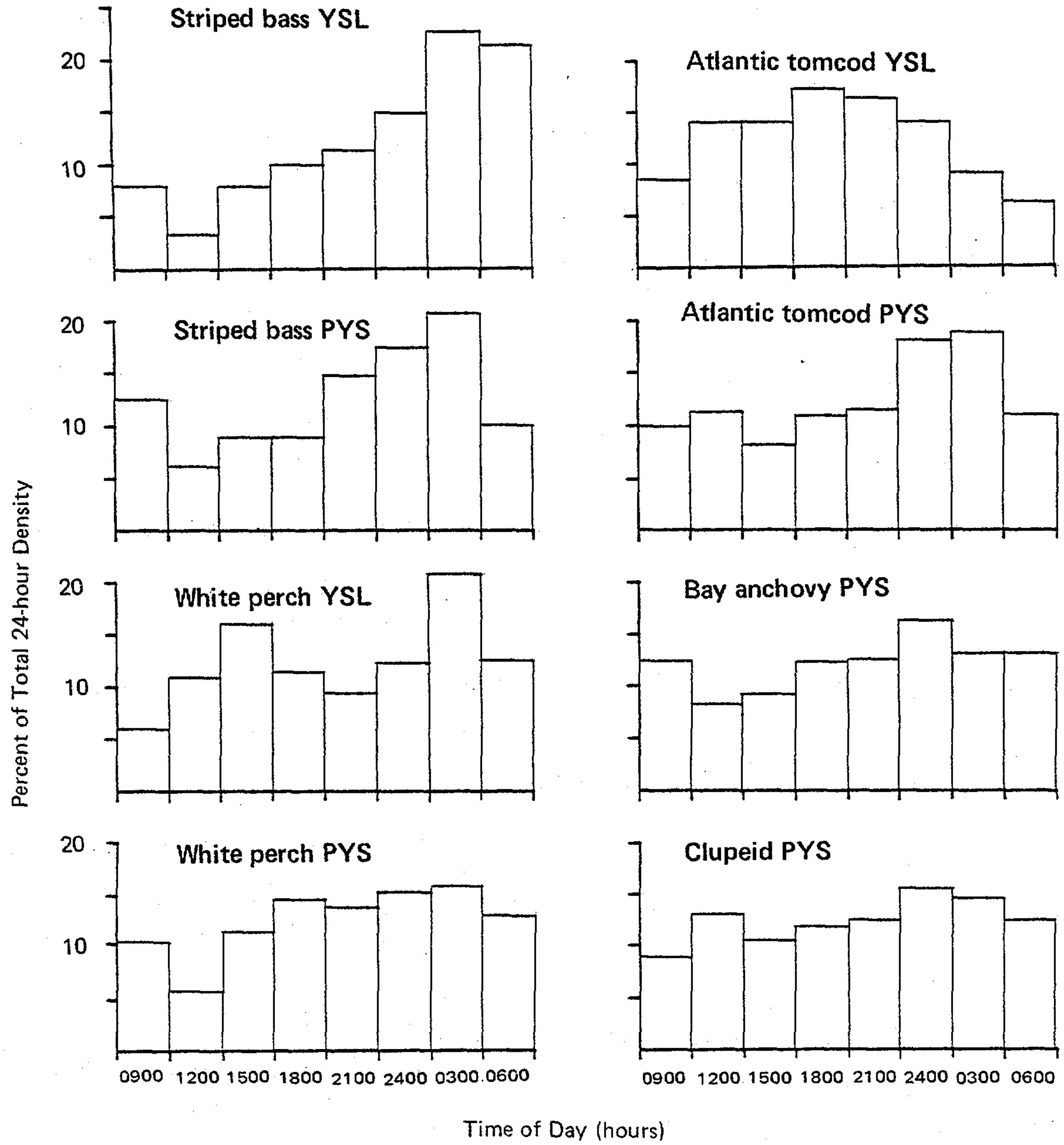

Figure 6-25. Diel distribution of the most abundant taxa collected at the Bowline Point plant discharge, 1977—1979.

Representative Monthly Plant Capacity Factors (Percent)

Month	Daytime (0600-2100 hours)	Nighttime (2100-0600 hours)
APR	81.2	52.9
MAY	79.9	59.6
JUN	80.8	61.8
JUL	84.3	71.1
AUG	78.1	61.7

The implication of this generation profile is that during the daily period of peak entrainment for the most abundant taxa the plant operates at its daily minimum resulting in lower thermal discharges. Consequently, the exposure to thermal stress on a daily basis is minimized for much of the entrained ichthyoplankton population.

One step in the analysis of entrainment impact is to determine the exposure of populations to entrainment in the plant condenser cooling systems (McFadden 1977, Chapter 6). Since variation in total mortality rates during early life stages (particularly post yolk-sac larvae and early juveniles) can affect year class strength (TI 1980a), which in turn determines spawning stock abundance, a comparison of the river regional and entrainment densities for post yolk-sac larvae can provide an indication of exposure of a year class to entrainment. During the three years (1977 through 1979) for which pumped sampling data are available at the discharge, entrained densities of white perch and striped bass were lower (Figure 6-26) than densities in the Croton-Haverstraw Bay region (river miles 34-39). Densities of striped bass post yolk-sac larvae in the shoal strata (TI 1980a and b, Figure 6-26), Bowline Pond (LMS 1978, 1979), and the plant are comparable, indicating that in general the population entering Bowline Pond and exposed to entrainment is withdrawn primarily from the shoal strata. White perch entrainment densities were lower than observed in any of the three strata sampled by TI (shoal, channel, and bottom), and were also less than Bowline Pond densities. The differences observed between the plant and the river indicate that the susceptibility of white perch and striped bass population to entrainment is low because of limited exposure to the plant. This low exposure index is further demonstrated by the proportion of the population entrained. Yearly estimates of the number of entrained post yolk-sac larvae (observed plant density x the volume of water pumped through the condenser system) were always less than 2 percent of the peak river-wide standing crops for both white perch and striped bass (Table 6-11, Appendix M). Furthermore, this estimate of the proportion entrained does not account for survival of these species, which ranges from 60 to 100 percent (Section 6.4).

6.3 ENTRAINMENT SURVIVAL

6.3.1 Introduction

During 1975 through 1979, EA sampled at the intake and discharge of the Bowline Point plant to estimate the effects of entrainment in the plant's once-through cooling water system on survival of ichthyoplankton. The basic treatment-control design of the study allowed estimates of survival following entrainment for ichthyoplankton collected at the discharge to

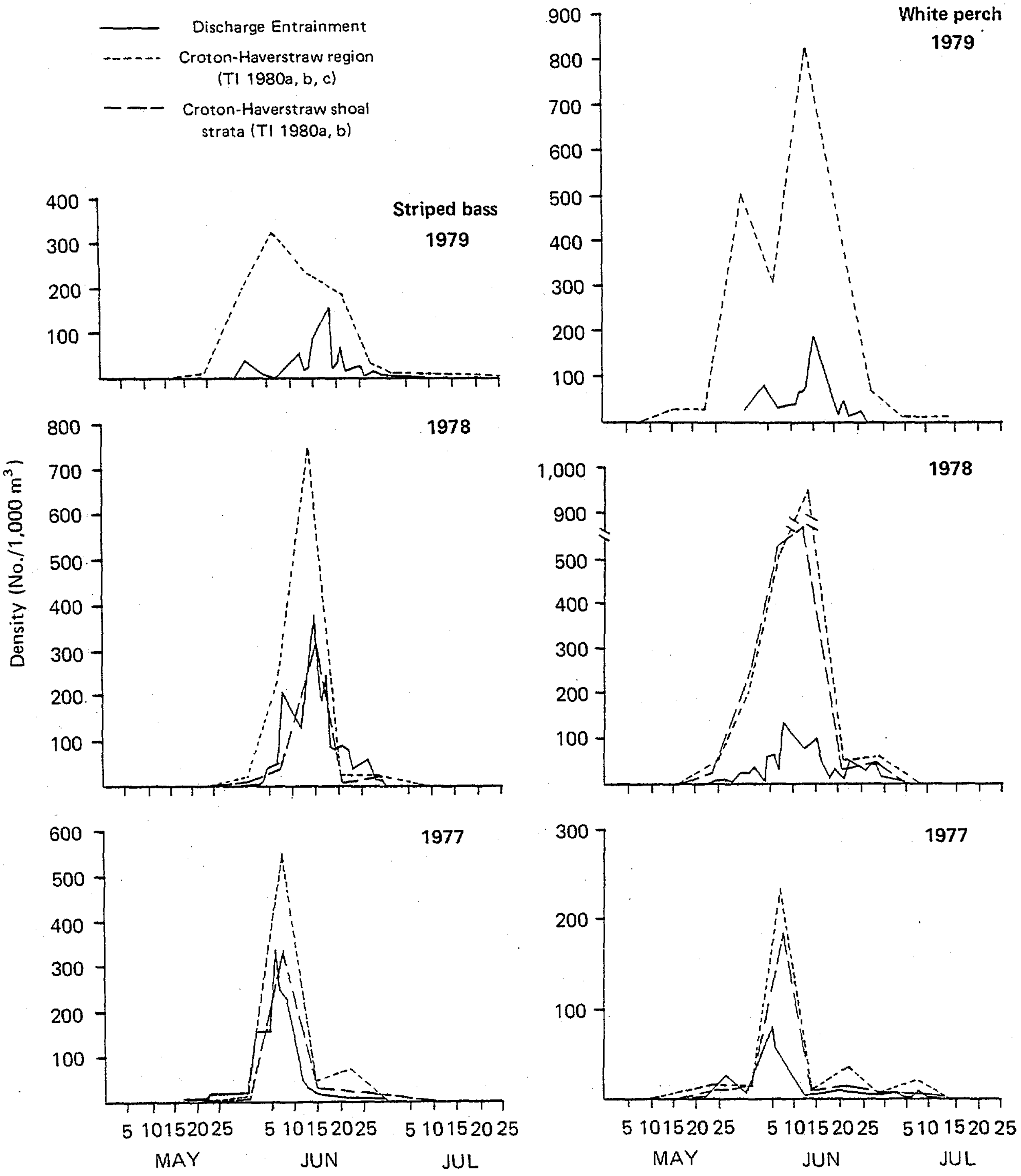

Figure 6-26. Density of white perch and striped bass post yolk-sac larvae collected at the Bowline Point plant discharge, and in the Croton-Haverstraw region of the Hudson River estuary, 1977–1979.

TABLE 6-11 SUMMARY OF THE NUMBER OF POST YOLK-SAC WHITE PERCH AND STRIPED BASS ENTRAINED AT THE BOWLINE POINT PLANT UNITS 1 AND 2 RELATIVE TO PEAK STANDING CROPS DURING 1975-1979

	Year	Estimated Numbers Entrained (Millions)	Peak Standing Crop (Millions)(a)	Percent Entrained
Striped bass	1979	1.5	314	0.5
	1978	7.8	439	1.8
	1977	7.1	559	1.3
	1976	3.2	242	1.3
	1975	2.2	717	0.3
White perch	1979	2.7	1,966	0.1
	1978	5.6	2,827	0.2
	1977	2.3	1,847	0.1
	1976	1.6	2,080	0.1
	1975	3.8	1,378	0.3

(a) Adapted from TI 1978, 1979, 1980a, 1980b, and 1980c.

then be adjusted for the effects of sampling stress reflected by survival of ichthyoplankton collected before entering the cooling water system at the plant intake.

Initial survival was determined from the number of live and dead ichthyoplankton collected, and extended survival of live organisms was monitored for 96 hours to evaluate latent effects of entrainment. Two phases constituted the entrainment survival studies:

1. The wild larval populations were sampled at natural abundance levels in the river.
2. Artificially propagated striped bass were released in high concentration at the intake and sampled by the same procedure as wild larvae to provide a larger data base with which to evaluate survival.

Most of the effort during these studies was expended during the periods of peak spawning and use of the estuary as a nursery area by larval and early juvenile life stages. Atlantic tomcod, striped bass, white perch, clupeids, and bay anchovy were studied.

6.3.2 Methods and Materials

6.3.2.1 Procedures Used to Assess Entrainment Survival of Wild Ichthyoplankton

6.3.2.1.1 Sampling Schedule

Survival samples in 1979 were collected during the peak period of ichthyoplankton abundance as reflected by discharge abundance studies (Section 6.2). Samples were collected on 3-5 days each week; generally seven samples were collected daily between 1400 and 2200 to coincide with the diel period of peak abundance. Daily sampling was conducted 19 times during May and June (Table 6-12). The Bowline Point plant generated electric power during only one week of the sampling season (18-22 June); however, the circulating water pumps were operated during the remainder of the season (14 days) to provide estimates of mortality related to mechanical stress of entrainment in the absence of thermal discharge.

The sampling efforts for each year from 1975 through 1978 are detailed in the respective annual reports (EA 1976, 1977b, 1978d, 1979a) and is summarized below:

Year	Sampling Season	No. of Days	No. of Samples
1979	23 MAY-27 JUN	19	435
1978	13 MAR-21 JUL	40	547
1977	7 MAR-15 JUL	46	736
1976	15 MAR-29 JUL	39	688
1975	3 JUN-25 AUG	37	400

6.3.2.1.2 Sample Collection

Although the basic experimental design with comparable intake and discharge sampling was similar from 1975 through 1979, a number of modifications were

TABLE 6-12 SUMMARY OF ENTRAINMENT VIABILITY SAMPLING EFFORT FOR WHITE PERCH AND STRIPED BASS AT THE BOWLINE POINT PLANT, 1979

	Number of Runs			
Date	Intake Pump Table	Intake Rear-Draw Flume	Discharge Standpipe	Discharge Diffuser
23 MAY	3	0	3	3
30 MAY	7	3	7	7
1 JUN	9	9	9	9
4 JUN	9	9	9	9
7 JUN	8	8	8	8
8 JUN	8	8	8	8
11 JUN	7	5	7	7
12 JUN	3	3	3	3
13 JUN	2	0	2	2
14 JUN	9	9	9	9
15 JUN	8	8	8	8
18 JUN(a)	7	7	7	7
19 JUN(a)	3	3	3	3
20 JUN(a)	3	3	3	3
21 JUN(a)	8	8	8	4
22 JUN(a)	1	2	2	2
25 JUN	2	2	2	2
26 JUN	9	9	9	6
27 JUN	8	8	8	4

(a) Plant was generating power; on all other days the circulating water pumps operated with no thermal discharge from the plant.

made to the collection gear (Table 6-13) and procedures (Table 6-14) in an effort to minimize sampling stress.

The pump/larval table collection system used for Atlantic tomcod sampling consisted of a modular one-screen collection flume (Figure 6-27), modified from the design of McGroddy and Wyman (1977). Sample water was delivered to the table by a 10-cm (4-in.) diameter Homelite centrifugal pump (two-vane open impeller) capable of passing solids up to about 5 cm in diameter. The flow rates and volumes of water pumped into each collection system were monitored with inline Sparling "Masterflo" flowmeters. The total volume of water sampled at each system during the standard 15-minute sampling interval ranged from 7 to 18 m^3. Water was drawn from middepth (4.6 m) at the intake through a 10-cm diameter flexible hose lowered perpendicularly to the intake flow. A similar hose was used to sample from approximately 2 m into the discharge standpipe. EA (1979a) reported that increased damage to the organisms and sampling mortality may have been related to head increase between 1977 and 1978 efforts. To reduce the sampling suction head at the intake, therefore, both the table and pump were mounted on a raft (Figure 6-28).

Samples were collected and concentrated in the larval tables which are approximately 4 m long, 1.2 m wide, and 0.6 m deep (Figure 6-27). The front of each table expanded from the 10-cm (4-in.) diameter hose opening to full table width, thus reducing the velocity and turbulence of the pumped water. At the end of the expansion section, a directional screen (505-µm mesh) diverted organisms, debris, and a small portion of the water into a collection box. A Q2 valve controlled the flow of water through the collection box and was also used to drain the collection box at the end of the sampling interval. The remaining water exited through the overflow weirs behind the directional screens. Valves adjacent to the overflow weirs (Q1 valves) were used to drain the table at the end of the sampling interval. The time required to rinse and drain the collection systems was approximately 15 minutes.

Each sample taken with the pumped larval table was collected by pumping water through the system for 15 mintues. Before sampling, the pumps were started and the tables were filled with water. The speed of the pumps was adjusted to 1550-1650 rpm and maintained at this speed throughout sample collection. A removable calibration net (505-µm mesh) inserted near the front of each table prevented contamination of the sample with organisms that may have been collected during the start-up period.

Sampling was initiated simultaneously at intake and discharge stations by removing the calibration net from each larval table. At the end of the 15-minute sampling interval, the pump at each station was turned off and the table was drained. The table was continuously rinsed with a gentle flow of filtered ambient temperature river water during draining. After the sample was concentrated into the collection box, organisms and detritus were drained through a 3-cm vinyl tube into a detachable transportation container, and transferred to the onsite laboratory for sorting. The larval tables were thoroughly rinsed between samples with a high pressure spray wash to prevent contamination of subsequent samples by detritus and/or organisms adhering to the sides of the table and screens. The concentrate from this wash was preserved in buffered formalin.

TABLE 6-13 SAMPLING GEAR USED TO COLLECT ICHTHYOPLANKTON FOR ENTRAINMENT VIABILITY AT THE BOWLINE POINT PLANT

Year	Station(a)	Sampling(b) Gear Construction Material	Number of Screens	Mesh(c) Size (μ)	Collection Box Type	Sample Container Type	Hose Type	Number(d) of Pumps	Pump Type(e)	rpm
1975	Intake	Plywood	2	505	Lift basket	Open box	4-in. flex	1	Midwhirl	--
	D2	Plywood	2	505	Lift basket	Open box	4-in. flex	1	Midwhirl	--
1976 (winter)	Intake	Plywood	2	505	Lift basket	Open box	4-in. flex	1	Midwhirl	800
	D2	Plywood	2	505	Lift basket	Open box	4-in. flex	1	Midwhirl	800
1976 (summer)	Intake	Plywood	2	505	Siphon	Closed box	4-in. flex	1	Midwhirl	800
	D2	Plywood	2	505	Siphon	Closed box	4-in. flex	1	Midwhirl	800
1977	Intake	Aluminum	2	505	Siphon	Closed box	4-in. flex	2	Homelite	1,700
	D1	Aluminum	2	505	Siphon	Closed box	4-in. flex	1	Homelite	1,700
	D2	Aluminum	2	505	Siphon	Closed box	4-in. flex	1	Homelite	1,700
1978 (regular)	Intake	Aluminum	2	505	Siphon	Closed box	4-in. flex	1	Homelite	1,800
	D1	Aluminum	2	505	Siphon	Closed box	4-in. flex	1	Homelite	1,800
	D2	Aluminum	2	505	Siphon	Closed box	4-in. flex	1	Homelite	1,800
	Diffuser	Aluminum	1	505	Siphon	Closed box	4-in. flex	0	--	--
1978 (special)	Intake	Aluminum	1	505	Siphon	Closed box	4-in. flex	1	Homelite	1,200
	D1	Aluminum	1	505	Siphon	Closed box	4-in. flex	1/0	Homelite	1,200
	Diffuser	Aluminum	1	505	Siphon	Closed box	4-in. flex	0	--	--
1979(g) (pump)	Intake	Aluminum	1	505	Siphon	Closed box	4-in. flex	1	Homelite	1,550
	D1	Aluminum	1	505	Siphon	Closed box	4-in. flex	1	Homelite	1,650
1979(h) (no pump)	Intake	Aluminum	2	505	Siphon	Closed box	4-in. flex	0	--	--
	Diffuser	Aluminum	2	505	Siphon	Closed box	4-in. flex	0	--	--

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(a) D1 = Unit 1 discharge; D2 = Unit 2 discharge; diffuser = Unit 1 diffuser.

(b) Intake orifice 1.0 m above ground level; intake orifice at water level in 1979 pumpless samplers.

(c) 350-μm mesh used in regular sampling for striped bass yolk-sac larvae, 22 May - 3 June 1978.

(d) No pump was required at diffuser; D1 used no pump when head in discharge standpipe was sufficient to start water siphoning (1978 only)

(e) Midwhirl intake orifice 1.5 m above ground with vortex impeller; Homelite intake orifice 0.5 m above ground with open-face centrifugal impeller.

(f) Special anchovy study.

(g) Standard one-screen pumped samplers.

(h) Floating ichthyoplankton sampling headers - pumpless.

TABLE 6-13 (EXTENDED)

Year	Station(a)	Method of Flow Determination	Flow (liters/minute)	Pump to Water Surface (m)	Hose Intake to Water Surface (m)	Hose Intake Orientation to Flow(b) (degrees)	Pump to Table (m)	Elevation of Hose Above Water Surface			
								Before Pump		After Pump	
								Max.	Min.	Max.	Min.
1975	Intake	0.9 m^3 overflow box	470-600	4-5	8	90	7.5	5.0	3.0	7.0	4.5
	D2	0.9 m^3 overflow box	470-600	3-5	2	90	7.5	8.0	5.0	7.5	5.0
1976 (winter)	Intake	Tableweir	250-1,420	4-5	8	90	7.5	5.0	3.0	7.0	4.5
	D2	Tableweir	375-1,300	3-5	2	90	7.5	8.0	5.0	7.5	5.0
1976 (summer)	Intake	Tableweir	250-1,420	4-5	8	90	7.5	5.0	3.0	7.0	4.5
	D2	Tableweir		3-5	2	90	7.5	8.0	5.0	7.5	5.0
1977	Intake	Flowmeter	500-1,200	2	4-7	90	3.0-3.5	0.5	0.5	5.5	3.5
	D1	Flowmeter	800-1,300	2-4	2	90	6.0	8.0	4.0	6.0	4.5
	D2	Flowmeter	800-1,300	2-4	2	90	7.5	7.0	4.0	6.0	4.5
1978 (regular)	Intake	Flowmeter	500-1,150	4-5	6-8	0	3.0	5.0	3.0	7.0	4.5
	D1	Flowmeter	200-1,400	2-4	2	0	7.5	8.0	4.0	6.0	4.5
	D2	Flowmeter	800-1,025	2-4	2	90	7.5	7.0	4.0	6.0	4.5
	Diffuser	Tableweir	150-400	--	4-6	0	--	0.5	0.5	1.0	1.0
1978(c) (special)	Intake	Tableweir	150-500	2	6-8	0	1.0	0.5	0.5	1.0	1.0
	D1	Tableweir	60-1,000	2-4	2	0	7.5	7.0	4.0	6.0	4.5
	Diffuser	Tableweir	150-400	--	4-6	0	--	0.5	0.5	1.0	1.0
1979(d) (pump)	Intake	Flowmeter	725-1,250	2	5	90	6.0	0.5	0.5	1.0	1.0
	D1	Flowmeter	700-950	2-4	2	90	30.0	8.0	4.0	6.0	4.5
1979(e) (no pump)	Intake	Flowmeter	750	--	5	0	--	0.0	0.0	0.0	0.0
	Diffuser	Flowmeter	625-800	--	4-6	0	--	0.0	0.0	0.0	0.0

(a) D1 = Unit 1 discharge; D2 = Unit 2 discharge; diffuser = Unit 1 diffuser.

(b) Semi-rigid flex hose deployed perpendicular to current and swept in direction of current by force of water; in 1978, suction hoses were positioned facing current; in 1979, suction hoses to pumpless samplers were positioned facing current.

(c) Special anchovy study.

(d) Standard one-screen pumped samplers.

(e) Floating ichthyoplankton sampling headers - pumpless.

TABLE 6-14 SAMPLING PROCEDURE SUMMARY FOR ICHTHYOPLANKTON VIABILITY COLLECTIONS

Year	Station(a)	Sample Duration (min)	Table Drain Time (min)	Sample Volume (m^3)	No. of Table Weir Drains	No. of Q1 Drains	Q2 Flow Rate (liter/minute)		
							Sample	Table Drain	Collection Box Drain
1975	Intake	15	30	7.0-9.0	1	0	600	600	600
	D2	15	30	7.0-9.0	1	0	600	600	600
1976(b)	Intake	15	30	3.5-21.0	1	0/2 pair(c)	600/76(c)	600/133(c)	600/38(c)
	D2	15	30	5.5-19.5	1	0/2 pair(c)	600/76(c)	600/133(c)	600/38(c)
1977	Intake	15	30	7.5-18.0	1 pair	2 pair	76	133	38
	D1	15	30	12.0-19.5	1 pair	2 pair	76	133	38
	D2	15	30	12.0-19.5	1 pair	2 pair	76	133	38
1978	Intake	15	30	7.8-15.4	2 pair	2 pair	76	133	38
	D1	15	30	4.7-21.5	2 pair	2 pair	76	133	38
	D2	15	30	11.5-15.0	2 pair	2 pair	76	133	38
	Diffuser	30	10	11.1	1 pair	1 pair	0	50	50
1978(d)	Intake	10	10	3.2-5.6	1 pair	1 pair	0	50	50
	D1	10	10	0.6-11.8	1 pair	1 pair	0	50	50
	Diffuser	10	10	2.6-4.8	1 pair	1 pair	0	50	50
1979(e)	Intake	15	17	11.9-17.7	1 pair	1 pair	50-100	100-200	50
	D1	15	17	7.4-15.4	1 pair	1 pair	76	133	38
1979(f)	Intake	15	15	9.8-14.2	1 pair	1 pair	50-100	100-200	50
	Diffuser	15	13	6.9-13.5	--	1 pair	76	133	38

(a) D1 = Unit 1 discharge; D2 = Unit 2 discharge.

(b) Where two entries occur in 1976, the first indicates procedure for winter season and the second indicates procedure for summer season after modification of larval table collection area.

(c) Modifications to table design for summer sampling incorporated decreases in Q2 drain rate and addition to Q1 drains.

(d) Special anchovy study.

(e) Standard one-screen pumped samplers.

(f) Floating ichthyoplankton sampling headers - pumpless.

TABLE 6-14 (EXTENDED)

Year	Station(a)	Method Collection Box Drain	Wash Water	Ambient Dilution System	Simultaneous Collection	Codends
1975	Intake	Into cooler	Ambient			Runoff
	D2	Into cooler	Discharge			Collection boxes
1976(b)	Intake	Cooler/siphon	Ambient		✓	Collection box
	D2	Cooler/siphon	Discharge		✓	Collection box
1977	Intake	Siphon	Ambient	✓	✓	Collection box
	D1	Siphon	Ambient	✓	✓	Collection box
	D2	Siphon	Ambient	✓	✓	Collection box
1978	Intake	Siphon	Ambient	✓	✓	Collection box
	D1	Siphon	Ambient	✓	✓	Collection box
	D2	Siphon	Ambient	✓	✓	Collection box
	Diffuser	Siphon	Ambient		✓	Collection box
1978(c)	Intake	Siphon	Ambient		✓	Collection box
	D1	Siphon	Ambient		✓	Collection box
	Diffuser	Siphon	Ambient		✓	Collection box
1979(d)	Intake	Siphon	Ambient		✓	Collection box
	D1	Siphon	Ambient		✓	Collection box
1979(e)	Intake	Siphon	Ambient	✓	✓	Collection box
	Diffuser	Siphon	Ambient	✓	✓	Collection box

(a) D1 = Unit 1 discharge; D2 = Unit 2 discharge.

(b) Where two entries occur in 1976, the first indicates procedure for winter season and the second indicates procedure for summer season after modification of larval table collection area.

(c) Special anchovy study.

(d) Standard one-screen pumped sampler.

(e) Floating ichthyoplankton sampling headers - pumpless.

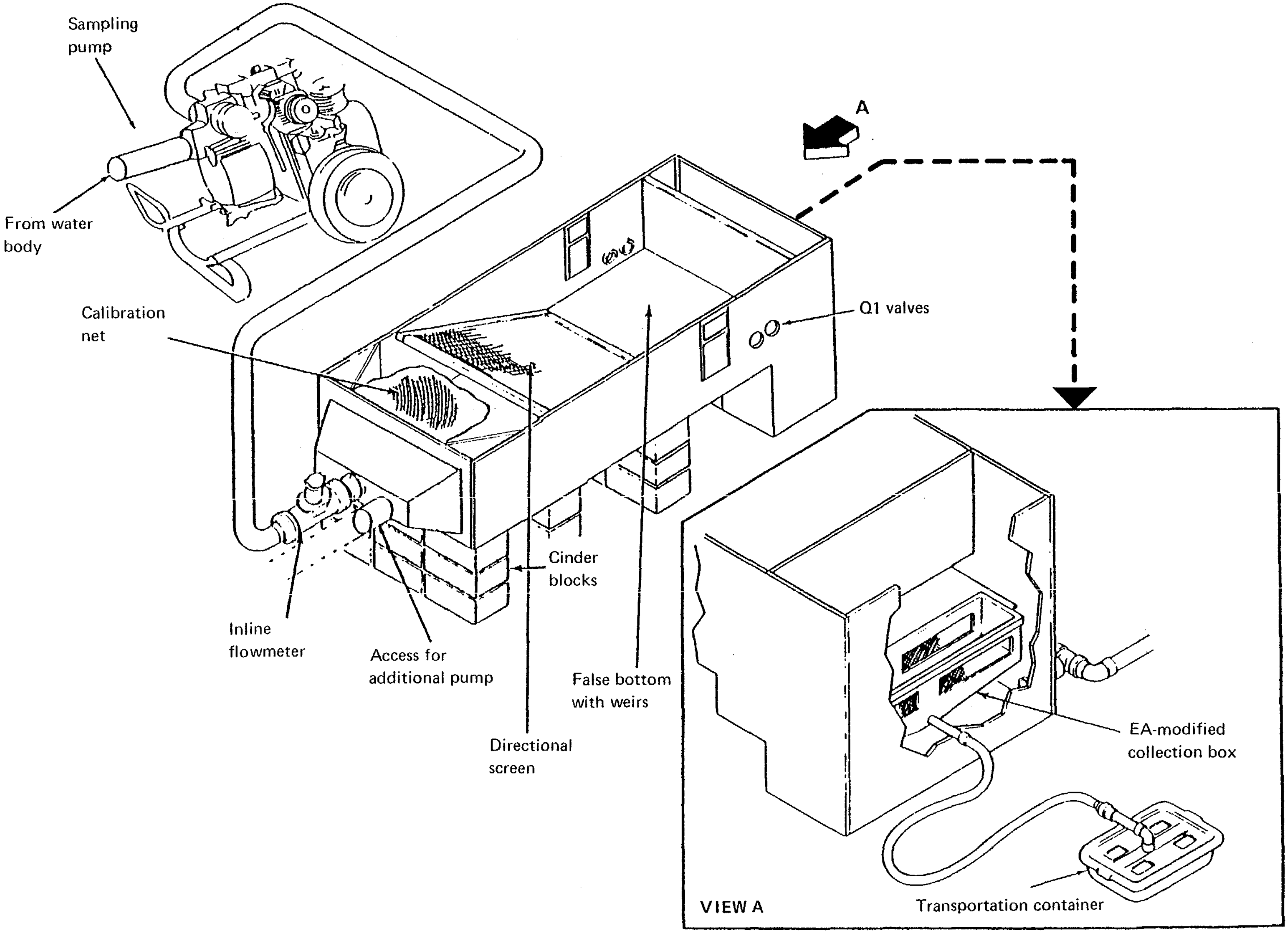

Figure 6-27. Design of larval table used to sample for entrainment viability studies at Bowline Point plant discharge.

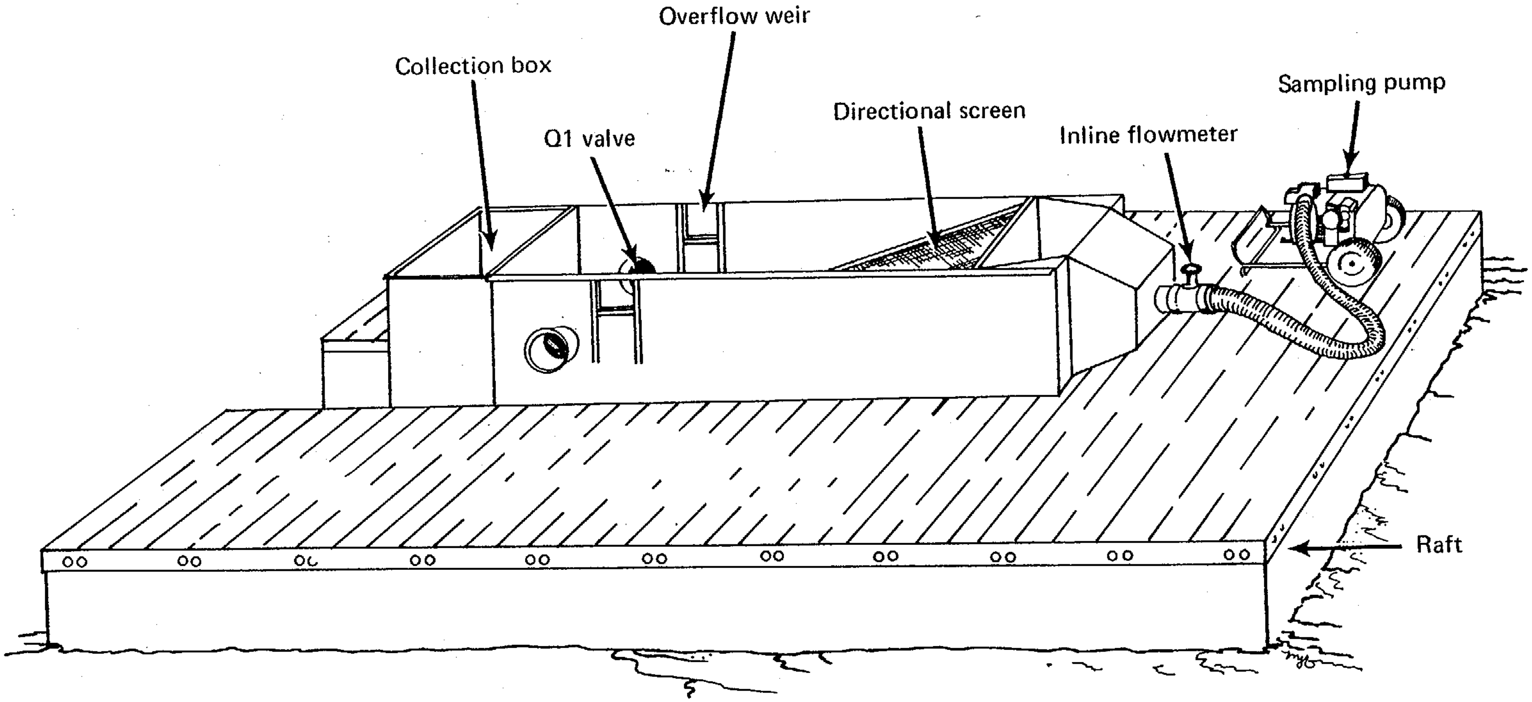

Figure 6-28. Design of the floating larval table used to sample the intake at the Bowline Point plant.

An ambient water injection system was used to reduce the exposure of organisms to elevated discharge temperatures during collection (Figure 6-29). This system injects filtered ambient river water into the larval table below the second false bottom at a rate of about 100 liters per minute, capable of reducing the delta-T in the collection system by approximately 35-50 percent at the discharge stations. Limiting the thermal exposure during collection was necessary because normal through-plant transit times are about 5-8 minutes as compared to a maximum 30-minute exposure in the larval table (sampling time plus table draining time). Because the plant was offline for most of the season, discharge temperatures were usually less than 30 C; therefore, this dilution capability was generally not required to minimize thermal stress during collection. However, the dilution also functioned as a continuous wash system during the sampling and washdown period.

In contrast to the pumped larval table collection systems, the pumpless and rear-draw plankton sampling flumes utilized head-induced flow rather than pumps for sample delivery. This design was developed to reduce sampling stresses on more sensitive ichthyoplankton taxa and life stages by eliminating potential mechanical and pressure effects associated with pump collection. The configuration of the intake and discharge flumes (e.g., length and width dimensions, orientation of the water inlet, flow expansion panels, divergence screens, ambient injection systems, and collection box) were the same (Figure 6-29) to minimize the potential of differential gear effects on organism survival.

The pumpless plankton sampling flume (2.4 x 1.2 x 0.6 m) was attached to the number 6 port on the Unit 1 discharge diffuser (Figure 6-30). The sampler was secured in a raft support structure so that the bottom of the flume was maintained at the river surface. Water and organisms exiting the discharge port entered a 10-cm steel 90°-sweep elbow mounted near the center and flush with the mouth of the port. The sample then passed through a length of flexible hose to the inlet of the collection flume. Dynamic head created by the water flow exiting the discharge port was sufficient to deliver water to the collection flume at a volume comparable to that at the rear-draw flume. Upon entering the collection flume, the temperature of the discharge sample was reduced by an ambient injection system that supplied a fine spray of ambient river water along the sides of the flow expansion panels, divergence screens, and collection box.

Organisms and detritus filtered by the two vertical 505-µm mesh screens were diverted into the collection box. Water passage through the sampler, as well as drainage and sample concentration, were achieved by gravity flow as the water level in the flume was above the river surface. Filtered water exited the collection system through a Q2 valve beneath the collection box and through Q1 outlets behind the vertical screens. Flexible hoses, attached to the Q1 outlets, could be raised or lowered to increase or reduce water flow through the system. Volume of sampled water was measured with a Signet inline flowmeter attached to the flume inlet. Volume filtered during each sample ranged from 7 to 18 m^3. The time required to drain the sampler ranged from 12 to 15 minutes.

The rear-draw plankton sampling flume, which measured 2.4 x 1.2 x 0.5 m, was mounted on a raft in front of the Unit 13 intake structure adjacent to the pumped larval table. The design of the flume and collection box components

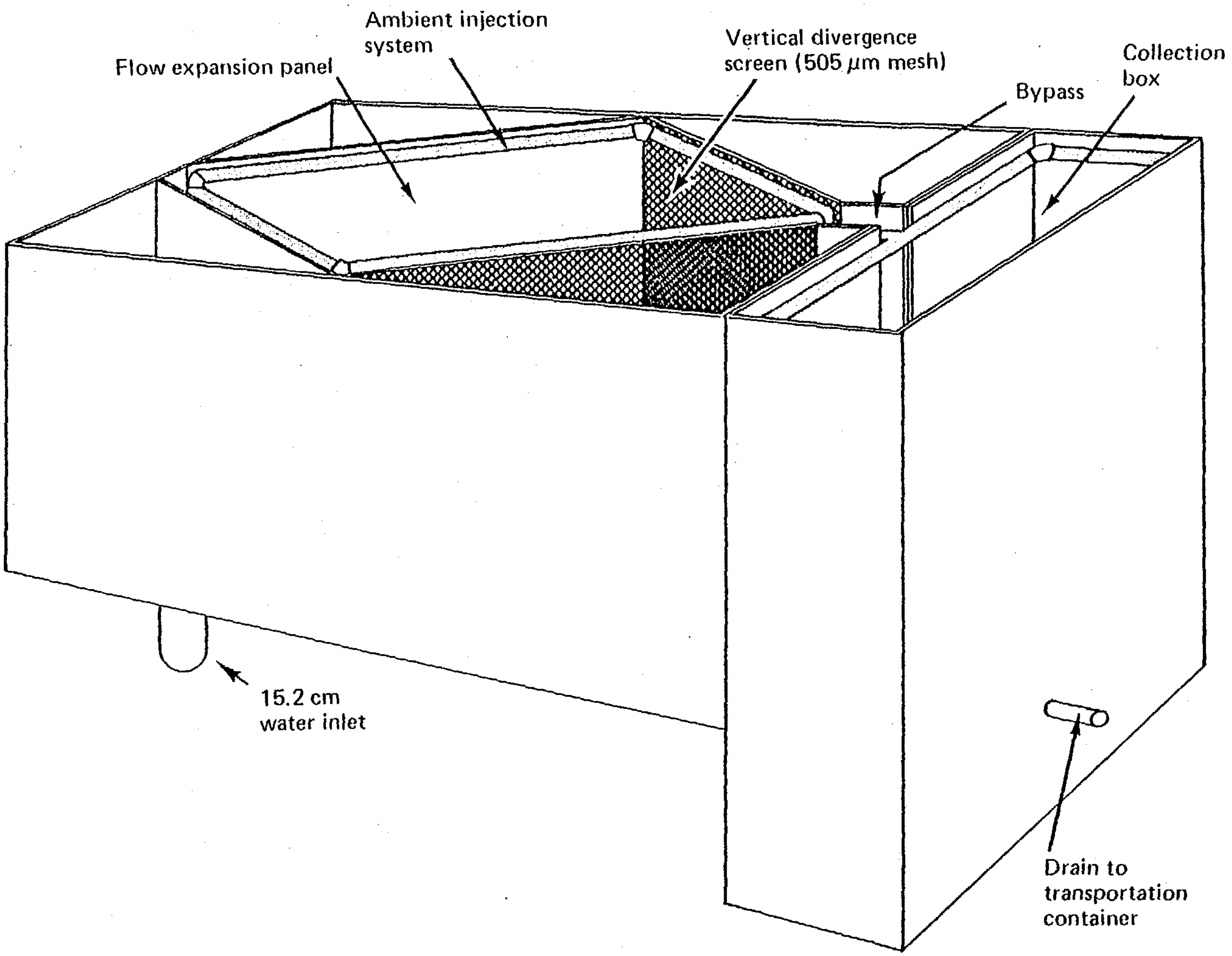

Figure 6-29. Design of the collection flume used in the pumpless and rear-draw samplers during the spring-summer entrainment survival study, Bowline Point plant, 1979.

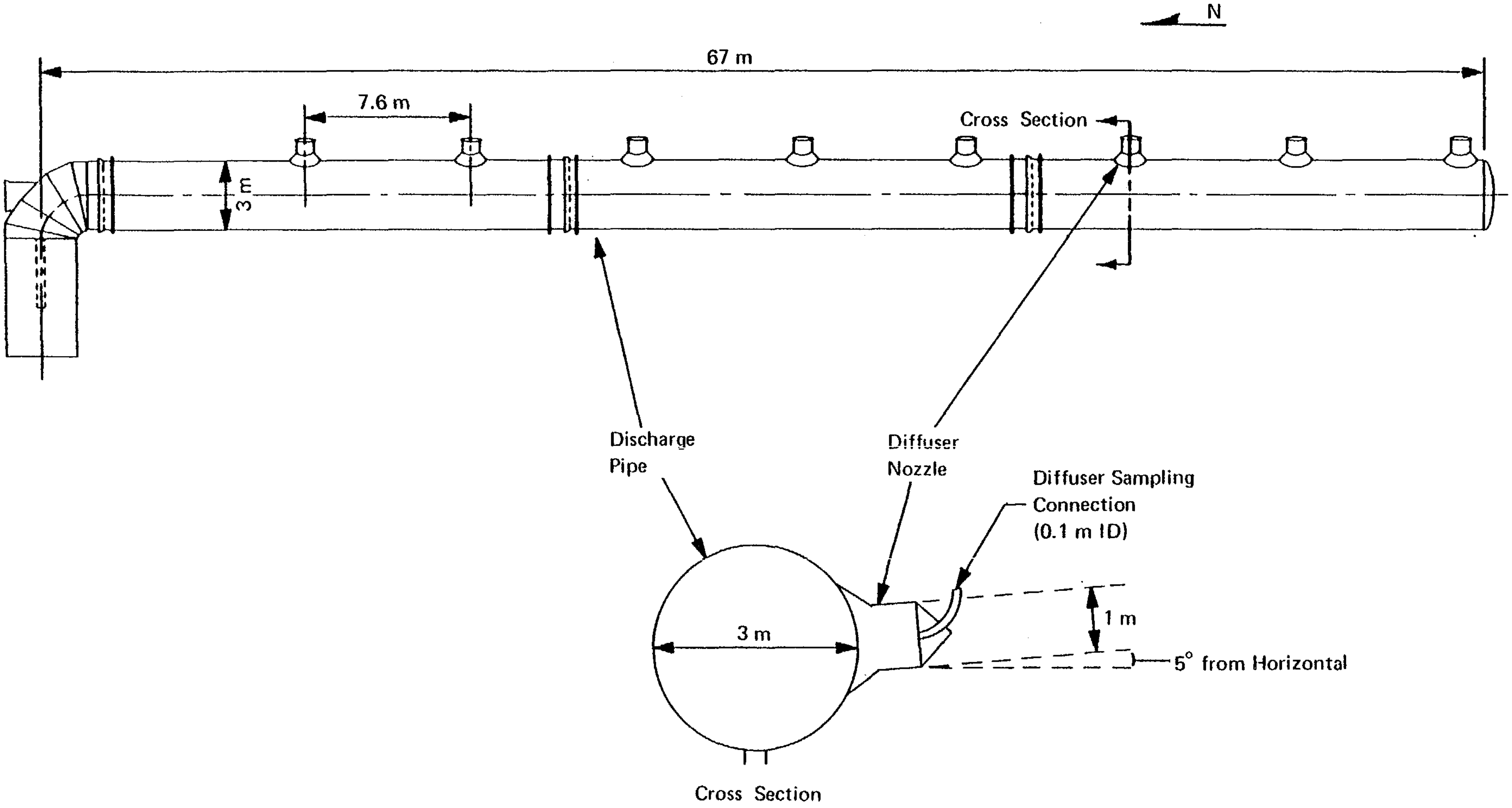

Figure 6-30. Design of Unit 1 diffuser and attachment of sampling apparatus to sixth diffuser nozzle at the Bowline Point plant.

of this sampler were consistent with those of the pumpless plankton sampling flume, and sample delivery was similarly implemented by head-induced flow. However, because the water velocities at this station (less than 1.0 fps) were insufficient to supply an adequate sample flow to the collection device, a head differential was created by submersing the bottom of the flume about 0.6 m below the river surface and pumping water out of the sampler from behind the angled 505-µm mesh diversion screens using a 10-cm (4-in.) Homelite pump. Water was also withdrawn through a Q2 valve beneath the collection box using a 1 hp Goulds pump, which recirculated water to the ambient wash system. Sample water entered the collection flume through a length of 10-cm (4-in.) diameter flexible hose attached to the flume inlet. The mouth of the hose, which faced into the intake flow, was suspended at a depth of 4.6 m. Volume sampled was measured with an inline Sparling "Masterflo" flowmeter attached to the Homelite pump, and ranged from 8 to 18 m^3 per sample.

Each sample collected with the pumpless or rear-draw plankton sampling flumes was taken by allowing water to flow through the gear for 15 minutes. Prior to sampling, the ambient wash systems were activated to fill the collection flumes with water, and the Homelite pump was started at the rear-draw sampler. Sampling was initiated simultaneously at the intake and discharge stations by removing the plugs from the flume inlets. The pumping rate at the intake station was adjusted to match the sampling flow at the discharge station. At the end of the sampling interval, plugs were placed in the flume inlets and the Homelite pump was turned off at the rear-draw sampler. To facilitate draining, the Q1 hoses on the pumpless (discharge) flume were lowered their full extent. The rear-draw (intake) flume was raised and the plugs were removed from the Q1 outlets. The ambient injection systems remained on until the samplers were nearly drained to rinse the contact surfaces of the flow expansion panels, diversion screens, and collection boxes. Rinsing of the interior of the samplers was also supplemented with a gentle flow of filtered ambient river water from a garden hose. Once the samples were concentrated in the collection boxes, the Q2 valves were closed, and the Q2 pump at the rear-draw sampler was turned off. Organisms and detritus were then drained through 3-cm tubes at the bottom of the collection boxes into detachable transportation containers, and the samples were transferred to the onsite laboratory for sorting. Drain time averaged approximately 15 minutes per sample. The flumes and collection boxes were thoroughly rinsed between samples with a high pressure spray wash to prevent contamination of subsequent samples from detritus and/or organisms adhering to the surface of the sampler.

Measurements of water temperature, conductivity, dissolved oxygen, and pH were taken during each sampling effort associated with either the late winter or spring-summer entrainment survival studies. Water temperature was recorded at each station during sample collection. Conductivity, dissolved oxygen, and pH were measured at one of the intake stations during the first, middle, and last collections on each sampling night using the following equipment or procedures:

Parameter	Primary Meter	Alternate
Conductivity (µmho/cm)	Martek (MK V)	YSI, SCT (Model 33)
Dissolved oxygen (ppm)	Martek (MK V)	Winkler titration
pH	Martek (MK V)	pH paper (Micro Essential Laboratory)

6.3.2.1.3 Sample Processing

During the course of the studies (1975 through 1979), modifications were instituted in the sample processing procedure to reduce handling and holding stress and improve survival; these changes are summarized in Table 6-15. In 1979, intake and discharge standpipe and diffuser samples were sorted simultaneously in an onsite laboratory. The general scheme for processing ichthyoplankton survival samples is shown in Figure 6-31). Larval and juvenile fish were classified as live, stunned, or dead, based on the following criteria:

Live:	swimming vigorously, no orientation problems
Stunned:	swimming abnormally or struggling; no movement except in response to gentle probing.
Dead:	no vital life signs; no body or opercular movement, no response to gentle probing.

Live and stunned fish were carefully transferred to separate holding containers (1-quart jars) with a ladle. A maximum of five larvae were placed in each container, which was aerated and maintained in an ambient water trough. Care was exercised to separate the larger larvae and juveniles from the very small larvae to reduce the possibility of cannibalism. Holding jars were aerated and maintained in an ambient water bath for 96 hours after collection. Dead specimens were placed in vials and preserved for later identification.* The sort time averaged 30 minutes (15 to 60 minutes) and depended on the amount of detritus and the number and age of the organisms.

Live and stunned organisms were reexamined at 3, 6, 12, 24, 48, 72, and 96 hours after sample collection, and any dead were removed from the holding jars and preserved. After 96 hours, all organisms remaining alive were preserved. On one sample day per week during 1979, all organisms which were alive (live and stunned) at 96 hours were transferred to long-term holding containers (1-gallon jars). The day on which the most organisms were collected each week was selected for long term latent effects studies to assure an adequate sample size. Organisms held beyond 96 hours were fed at 24-hour intervals. Latent effects observations on these samples were continued to determine if any considerable change in the survival rate was manifested during a protracted period of time. Latent effects observations were made daily. After 14 days all remaining larvae were preserved.

Identification was made to species and life stage based on the available literature (Table 6-2) and on a reference collection. All species were measured; if 50 percent or more of an organism was present, it was included in the analysis. Because of the difficulty in differentiating alewife and blueback herring during the early life stages, these two species were classified as clupeids; any other members of the family Clupeidae were speciated. All live and dead organisms in samples terminated at 96 hours were measured to the nearest millimeter. Fish held beyond 96 hours for long term latent effects were not measured because rapid growth during these early life stages would result in lengths which were not indicative of size at the time of entrainment.

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*All sorted ichthyoplankton were preserved in 5 percent buffered formalin; residual detritus and invertebrates were preserved in 10 percent buffered formalin.

TABLE 6-15 SAMPLE PROCESSING SUMMARY FOR ICHTHYOPLANKTON VIABILITY COLLECTIONS AT THE BOWLINE POINT PLANT, 1975 THROUGH 1979

Year	Sorting Containers	Simultaneous Sorting	Checking Procedure[a]	Holding Container	Aeration Used	Larvae Transfer Device	Life Stages Processed[b]	Number of Larvae Per Jar
1975	Cooler + quart jar + Pyrex dish		Single check	Quart jar	✓	Glass baster	Egg, YSL, PYSL, Juv	>5
1976 (winter)	Cooler + quart jar + Pyrex dish	✓	Single check	Quart jar	✓	Glass baster	YSL, PYSL, Juv	>5
1976 (summer)	Sample container	✓	Single check	Quart jar	✓	Glass baster	YSL, PYSL, Juv	5
1977	Sample container	✓	Single check	Quart jar	✓	Glass baster	YSL, PYSL, Juv	5
1978	Sample container	✓	Double check	Quart jar	✓	Glass baster	YSL, PYSL, Juv	5
1979	Sample container	✓	Double check	Quart jar	✓	Dipper	YSL, PYSL, Juv	5

(a) Checking procedure--single check was when one other person would check sample in same container; double check was when sample was concentrated after single check and sorted and checked again in a separate dish.

(b) Egg = Eggs; YSL = Yolk-sac larvae; PYSL = Post yolk-sac larvae; Juv = Juveniles.

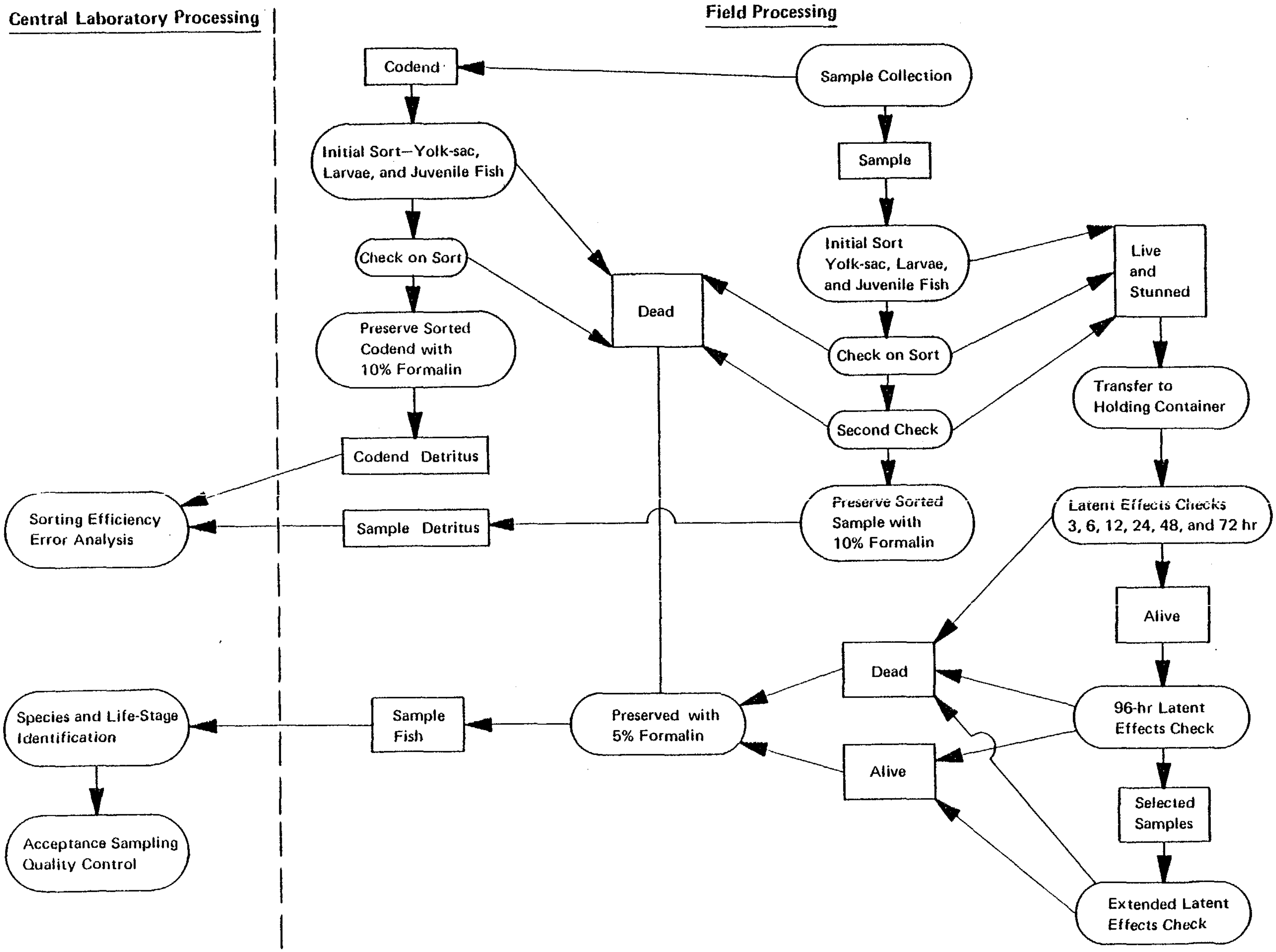

Figure 6-31. Work-flow chart for ichthyoplankton survival sample processing at the Bowline Point plant during 1975 through 1979.

6.3.2.1.4 Quality Control/Quality Assurance

Periodic inspections of the field sampling program were conducted by Ecological Analysts Documentation Control Office to ensure strict adherence to standard operating procedures.

Laboratory quality assurance procedures consisted of color-coded labels for jars and vials, records of the number of live and dead at each check time, and a double check of the sorted sample prior to preservation. Sorting efficiency and species/life stage identification accuracy and consistency were determined and documented. Organisms found in the sample or codend detritus were used to evaluate collection efficiency but were not entered in viability calculations. Acceptance sampling with rectification based on the Poisson distribution was used to assure the quality level of organism identification. This procedure required rework of a maximum of 20 randomly selected organisms from each identifier's effort in a given week for each species and life stage (white perch, striped bass, Atlantic tomcod, clupeids, and anchovy). The procedure provided an average outgoing quality level (AOQL) of no more than 10 percent error.

6.3.2.2 Field Procedures Used to Assess Entrainment Survival of Hatchery-Reared Striped Bass (Direct Release)

6.3.2.2.1 Sampling Schedule

In conjunction with the program to evaluate entrainment survival of Hudson River ichthyoplankton, studies were conducted during 1979 to determine the effects of the entrainment process under controlled conditions that would yield greater numbers of organisms per sample. Large groups of hatchery-reared striped bass eggs or larvae (approximately 40,000 to 75,000 individuals) were released directly into the flow of cooling water at the Bowline Point plant intake. The released organisms were subsequently collected in transit at the discharge standpipe and diffuser sampling stations.

Direct releases were conducted on 14 days from 21 May through 25 June with one release per sampling date. The total sampling effort is summarized below:

Release Organisms	Site of Release	Number of Releases	Total Estimated Number Released
Eggs*	Unit 1	3	225,000
Yolk-sac larvae*	Unit 1	3	216,438
Post yolk-sac larvae*	Unit 1	7	339,673
Post yolk-sac larvae	Unit 2	2	105,661

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* On 24 May 1979, the release included 75,000 eggs and 75,000 yolk-sac larvae.

6.3.2.2.2 Test Organisms

Fish used for releases were obtained from the Con Edison hatchery in Verplanck, New York on the day of the release to minimize handling stresses and to optimize survival. The hatchery organisms were transported in insulated containers to the release site and gently transferred to the flow-through holding/release tank.

This tank was set on a small dock near the intake structure. Hudson River water was aerated and circulated through the 242-liter (64-gallon) tank. The striped bass were allowed to acclimate to the holding device for 2 hours, prior to estimating the population size.

The population of striped bass used for a single release was too large to permit actual enumeration of individuals; therefore, an aliquot system was used to estimate the total number of organisms in each release group. Ten to twelve 800-ml aliquots were syphoned from the tank, while the contents were gently stirred to reduce the heterogeneous distribution of the test organisms in the container. Live and dead striped bass in each aliquot were counted immediately; the population estimate was calculated from these numbers (Section 6.3.2.3.3).

6.3.2.2.3 Testing Procedures

Test organisms were released following the aliquot counts. The holding/release tank was towed to the intake bar racks. A 10-ft section of PVC pipe connected to the tank drain was placed through the bar racks (Figure 6-32). The removal of the drain standpipe in the holding/release tank initiated the release. The tank took 2-4 minutes to drain and permitted release of the organisms between the bar racks and the traveling screens 0.33 m below the surface of the water. Sampling at the discharge pumped-abundance sampler began simultaneously with the release to determine the rate and duration of larval transit. The nets of the pumped sampler (Figure 6-33) were switched every 2 minutes and washed down to collect a minimum of eight individual samples. Fifteen-minute survival samples were initiated at the discharge and diffuser simultaneously with the release of organisms at the intake. The collection gear (pumped larval table and pumpless sampling flume) and procedures for discharge standpipe and diffuser sampling were identical to those described for wild ichthyoplankton (Section 6.3.2.1.2).

Survival at the intake was compared to the standpipe and diffuser survival to evaluate the effects of handling, collection, and holding stress. Intake control samples, as well as holding and gear calibration samples, were collected prior to each release. A portion of the striped bass were used as the control test organisms (Table 6-16).

Intake survival (control) was determined by replicate releases of 25 organisms in each intake sampling apparatus on each sample date. The control organisms were introduced into the inlet hose of the pumped larval table and the rear-drawm sampling flume (Figure 6-34). Fifteen-minute samples were then run in the same manner as described for wild ichthyoplankton. With the exception of differences in the release procedures, organisms at the intake were subjected to the same collection, handling, and holding stresses as those collected at the standpipe and diffuser. To monitor the effects of holding stress and the condition of each release population, replicate

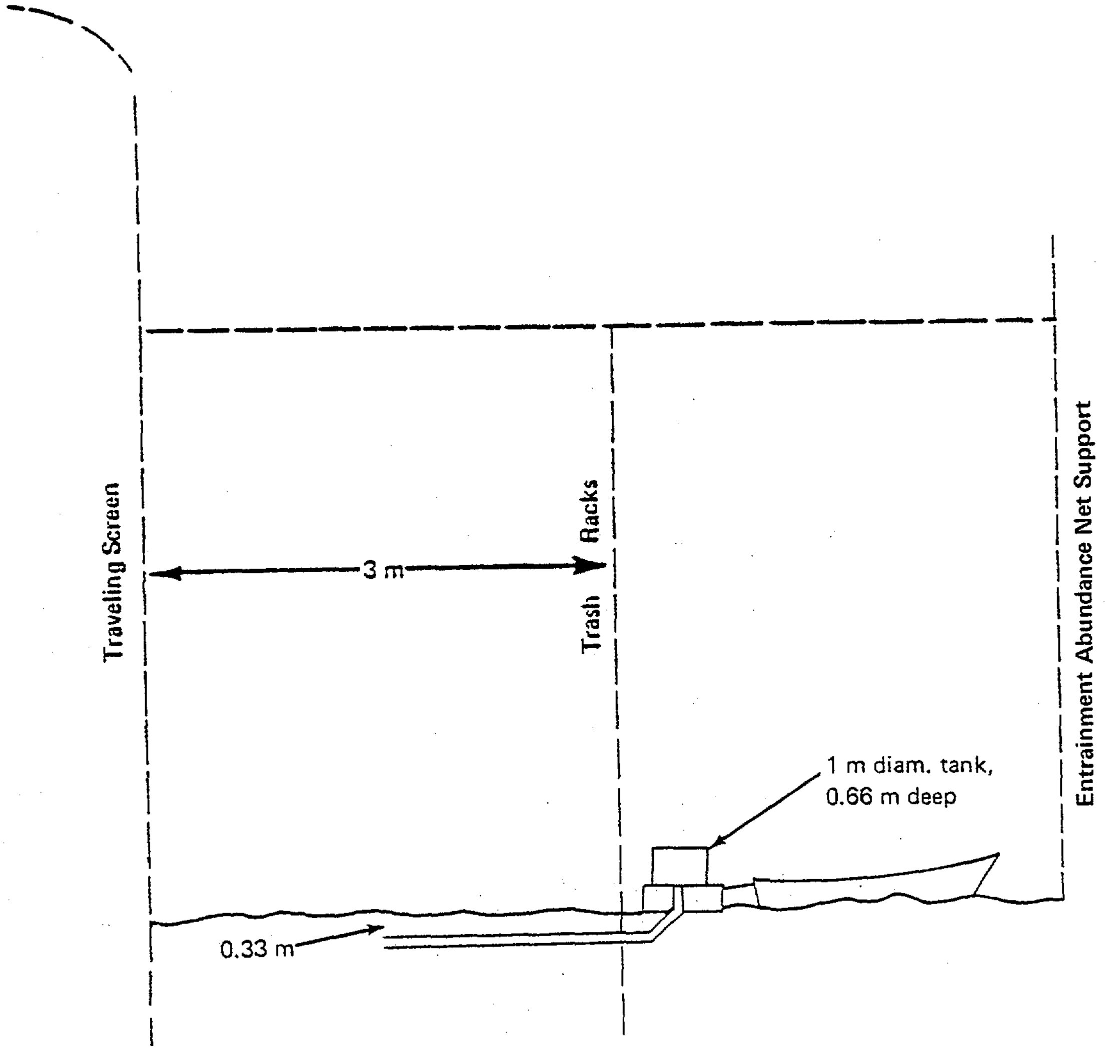


Figure 6-32. Location of release apparatus at intake for direct release studies.

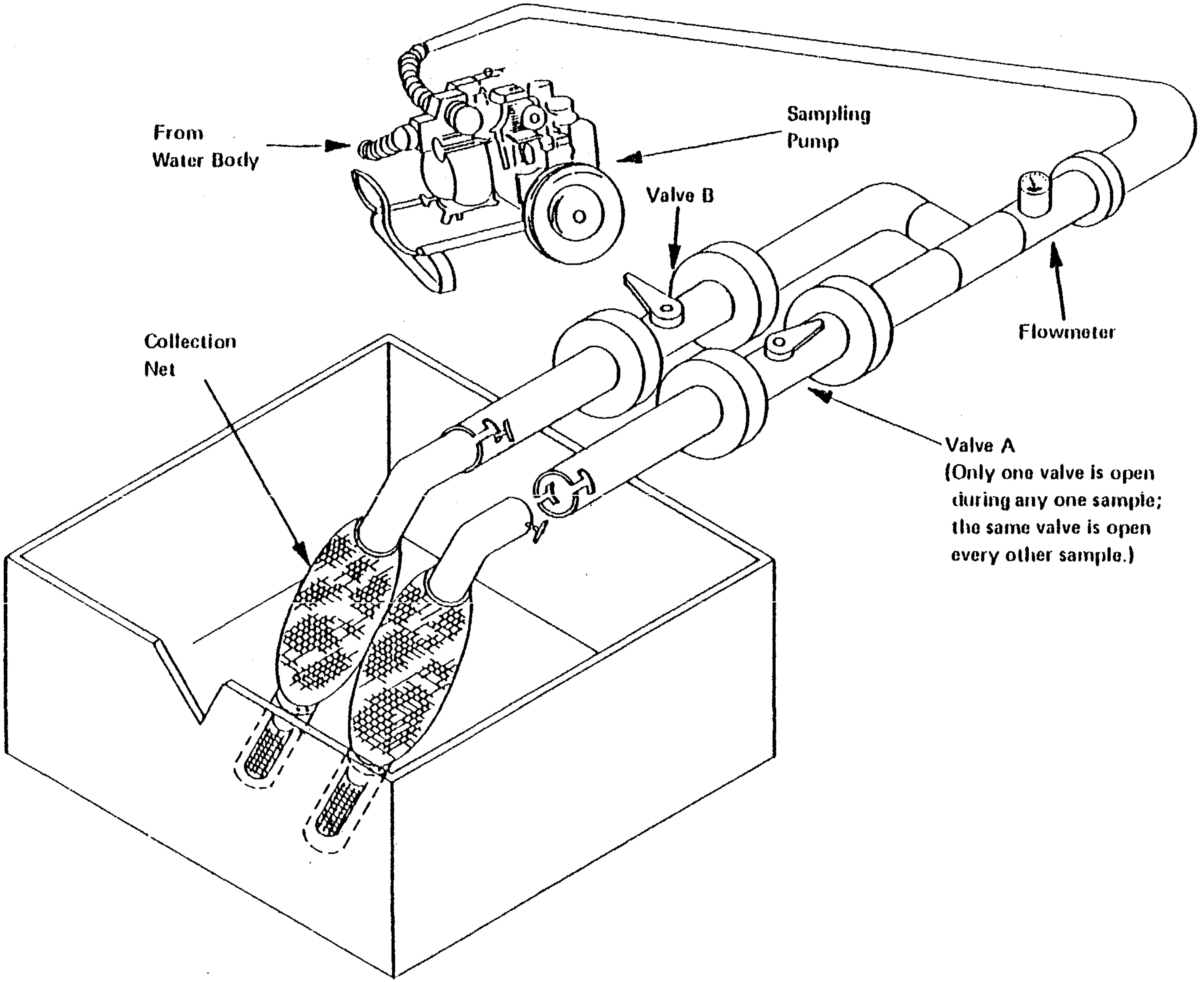


Figure 6-33. Schematic diagram of the manual abundance sampler used at the Bowline Point plant.

TABLE 6-16 SUMMARY OF CONTROL SAMPLING CONDUCTED DURING THE DIRECT RELEASE STUDIES AT THE BOWLINE POINT PLANT, 1979

Control Type	Stations Sampled	Method	No. Organisms Per Sample	No. Samples Per Release
Intake control	Intake w/pump	Organisms injected directly into mouth of the intake line of the sampling gear via a length of tubing (Figures 6.3.2-5).	25	2
	Intake w/o pump		25	2
Holding control	Onsite laboratory	Organisms transferred from the release/holding tank directly to the onsite laboratory and placed in a sample transport container for processing.	25	2
Gear calibration	Intake w/pump	Organisms injected into flow of water at the intake end of each sampling gear.	25	1
	Intake w/o pump		25	1
	Discharge		25	1
	Diffuser		25	1

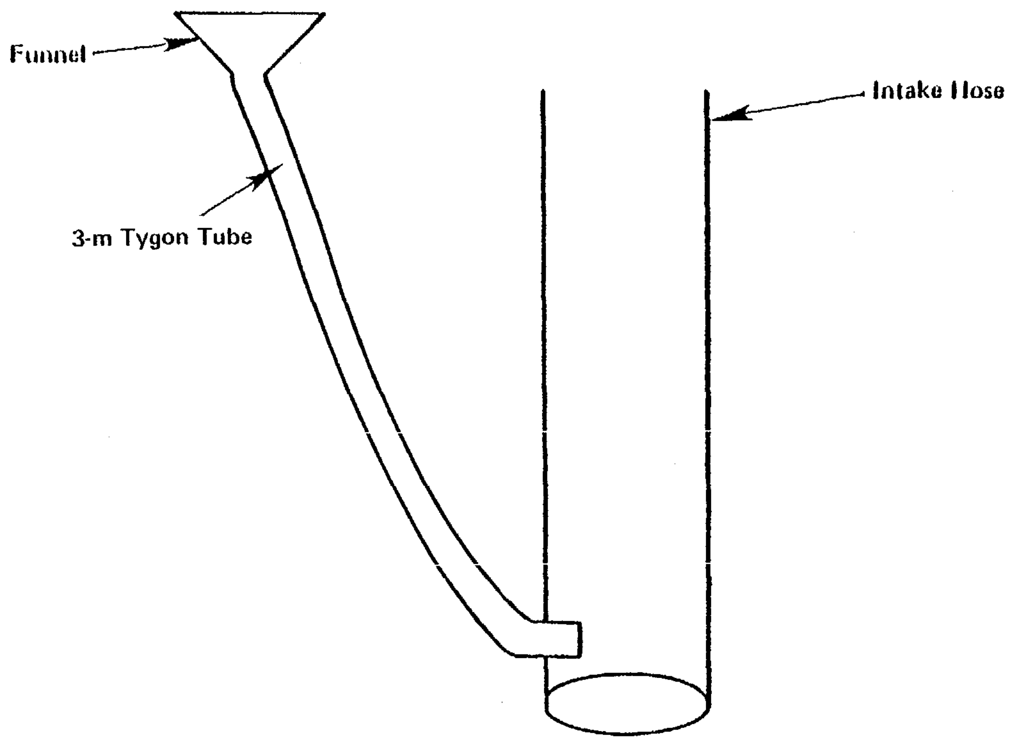


Figure 6-34. Schematic diagram of the hose injector system.

samples of 25 live fish were placed in the 1-liter holding jars (5 fish per jar) and held for 96 hours in the same manner as intake and discharge samples (Section 6.3.2.1.2). A third group of controls was conducted to evaluate the effect on survival of differences in configuration between the pumped larval table and the plankton sampling flume.

To quantify the number and condition of in situ (background) ichthyoplankton in sample, 15-minute collections were made before (presample) and after (postsample) each release at the discharge standpipe and diffuser. The average of the pre- and post-samples was used to adjust the number collected during the release for comparison with the calculated expected number.

The collection gear, methodology, and sample processing for all collections were the same as those employed for the standard entrainment viability studies. However, the processing of striped bass eggs required the special classification of live and dead eggs, based upon the following criteria:

Live: translucent, chorion complete, not cloudy in any internal portion.

Dead: Opaque, chorion ruptured, or cloudy in any internal portion.

Dead and hatched specimens were placed in vials and preserved at the initial sort and at each latent effects observation.

6.3.2.3 Analytical Procedures

6.3.2.3.1 Survival Proportions

The proportion of eggs that survived was determined on the basis of hatching success within 96 hours after collection, as shown in the equation below:

$$P_I \text{ or } P_D = \frac{\text{No. of eggs which hatched (96 hours)}}{\text{Total no. of eggs collected}}$$

where

P_I = proportion surviving at the intake station
P_D = proportion surviving at the discharge station

This method, which takes into account both initial and latent effects, was used because of the difficulty of visually determining live versus dead condition for the egg stage. The standard error of the survival proportion was calculated as:

$$\text{Standard error} = \sqrt{\frac{P\,(1-P)}{n}}$$

where

P = proportion of eggs surviving
n = total number of eggs collected

Initial survival proportions for larval and juvenile life stages collected at intake and discharge stations were calculated as the ratio of fish found alive or stunned immediately following collection to the total number of fish collected, as shown in the following equation:

$$P_I \text{ or } P_D = \frac{\text{No. of alive and stunned fish}}{\text{Total no. of fish collected}}$$

Stunned fish were grouped with live fish in the analysis to avoid potential bias associated with the subjective stunned categorization.

Extended survival of larval and juvenile life stages collected at intake and discharge stations was compared to determine if mortality caused by potential latent effects from entrainment was manifested beyond the initial survival observation. For these comparisons, survival at each extended survival observation was calculated as a proportion of the initial number of live and stunned fish (i.e., normalized survival) as follows:

$$P_{I_i} \text{ or } P_{D_i} = \frac{\text{No. of fish alive or stunned at time i}}{\text{Total no. of fish initially alive or stunned}}$$

where

P_{I_i} = normalized survival proportion at time i for fish collected at the intake

P_{D_i} = normalized survival proportion at time i for fish collected at the discharge.

Sources of variation in entrainment survival data were evaluated by means of log-linear likelihood ratio estimates using multidimensional contingency tables (Sokal and Rohlf 1969; Dixon and Brown 1977; and Brown 1976). This procedure tests for independence of effects and has been used primarily to assess the effect of length, year, circulating pump operating mode, discharge temperature and delayed mortality on the overall survival of entrained organisms. Where significant interactions are observed the G statistic can be partitioned to evaluate the interactions of specific components of an effect (e.g., specific circulator pump operating modes if a pump effect is demonstrated for survival).

Initial survival proportions for ichthyoplankton collected at the intake stations were pooled by life stage and species for all collections. To evaluate mechanical and thermal effects, the survival proportions were calculated for specific discharge temperature categories. Temperature categories for striped bass, white perch, herrings (clupeids), and bay anchovy were: (1) <30.0 C, (2) from 30.0 to 32.9 C, and (3) ≥ 33.0 C. Atlantic tomcod were only collected at discharge temperatures less than 18 C, below the lethal threshold for the species.

Survival proportions for studies conducted with hatchery-reared larvae were adjusted to account for the number of dead larvae collected that were dead at the time of release (N_{DR}). The proportion dead (D_R) determined in the population estimates was used to make this adjustment.

$$N_{DR} = N_T \times D_R$$
$$N_{TA} = N_T - N_{DR}$$
$$N_{DA} = N_D - N_{DR}$$

where

N_t = total number collected
N_D = total number dead at discharge (diffuser)
N_{TA} = adjusted total number
N_{DA} = adjusted number dead.

The adjusted number dead and total were then used to calculate the survival proportions as described above.

6.3.2.3.2 Entrainment Survival Estimates

Entrainment survival estimates for eggs were determined by comparing proportions that hatched within 96 hours for intake and discharge samples. All eggs which did not hatch by 96 hours were dead. For larval and juvenile life stages, entrainment survival estimates were based on the initial and 24-hour survival proportions for the intake and discharge stations. Survival at the discharge stations is the product of the conditional probabilities of surviving entrainment and sampling. Assuming there is no interaction between the two stresses:

$$P_D = P_s \times P_e$$

where

P_D = probability of surviving at the discharge
P_s = probability of surviving sampling
P_e = probability of surviving entrainment.

The intake survival proportion (P_I) was used as an estimate of P_s, and entrainment survival (S_e) was estimated using the equation:

$$S_e(\%) = P_e \times 100 = \frac{P_D}{P_I} \times 100$$

The value of S_e thus represents the percentage of organisms that survive passage through the plant cooling water system. Entrainment survival estimates for a particular species and life stage were calculated when the number of organisms collected per station or temperature category was 10 or greater. The standard error of the entrainment survival estimate was calculated with the equation (Fleiss 1973, p. 60):

$$\text{Standard error} = \frac{1}{P_I}\left[\frac{P_D\,(1 - P_D)}{N_D} + \frac{S_e{}^2\, P_I\,(1-P_I)}{N_I}\right]^{\frac{1}{2}}$$

where

N = number collected at the discharge (D) or intake (I).

6.3.2.3.3 Population Estimates for Release of Hatchery-Reared Striped Bass

The total number of striped bass released was estimated by converting the number of larvae in each aliquot to an estimate of the total population based on the ratio of the aliquot volume to the total tank volume.

$$T_p = \frac{T_A}{V_A} (V_t)$$

where

T_p = total population
T_A = total number of individuals in an aliquot
V_A = volume of aliquot
V_t = volume of tank.

The number of organisms released was then estimated by the mean of the 10 population estimates ± the standard deviation. Despite every effort to obtain homogeneity in the holding tank, fish tended to school and sample population estimates exhibited a high degree of variation around the mean.

Assuming homogeneous mixing of released organisms in the condenser cooling system (probably a valid assumption due to the velocity encountered), the predicted recovery at the discharge and diffuser sampling stations can be calculated as follows:

$$N_{pr} = (N_r) \frac{V_s}{V_c}$$

where

N_{pr} = predicted number of released organisms recaptured
N_r = number of organisms released
V_s = volume of water sampled
V_c = volume of water circulated through the plant for the duration of the sample.

The total number of larvae collected at the discharge and diffuser was adjusted to account for wild larvae. The average number of striped bass collected in the pre- and post-samples was subtracted from the total number of striped bass collected.

6.3.3 Results of 1979 Studies

6.3.3.1 Wild Populations of Ichthyoplankton

6.3.3.1.1 Description of the Entrained Population

The most abundant taxa during survival studies (Table 6-17) at the Bowline Point plant were the same and generally occurred during the same time period as observed during the 1979 abundant studies (Section 6.2.3). Post yolk-sac larvae was the predominant life stage collected for striped bass, white perch, bay anchovy, and clupeids.

The lengths of the most abundant taxa collected ranged from 3 to 25 mm with the majority less than 12 mm (Appendix J). When more than 10 organisms were collected at each station, the weekly mean lengths typically differed by less than 2 mm between the intake and discharge or diffuser. This consistency between stations indicates that similar populations were sampled at the intake and discharge.

The peak abundance of striped bass and white perch larvae occurred during mid-June when temperatures were between 20 and 23 C. Few large *Morone* (late post yolk-sac or juvenile) were collected, with the majority of striped bass between 6 and 12 mm. The range of lengths for striped bass was similar to that observed during previous sampling efforts (EA 1976, 1977b, 1978d, 1979a). White perch were smaller than striped bass with most larvae between 3 and 6 mm, as observed in 1978.

Clupeids were collected from late May to mid-June with the peak in early June. Lengths ranged from 4 to 25 mm, but the majority were less than 9 mm. Bay anchovy were most abundant during the second half of June; however, sampling ended before the mid-July peak observed during abundance studies. The majority of bay anchovy were between 3 and 9 mm and were collected between 10 and 24 C and at conductivities in excess of 1,100 µmhos/cm.

6.3.3.1.2 Initial Survival

Ichthyoplankton survival of sampling and handling stresses monitored at the intake with two gear types (pumped larval table and rear-draw sampling flume) varied by species and life stage (Table 6-18). Although abundance was low for some taxa and differences were typically not significant, organisms previously (1975-1978) found to be most sensitive to collection and handling (e.g., striped bass eggs, *Morone* yolk-sac, and bay anchovy) generally exhibited higher survival in the flume than the pumped table. Initial survival of yolk-sac striped bass was higher in the flume (1.00) than in the pumped table (0.83). White perch yolk-sac survival followed a similar pattern, although abundance and survival (0.11 and 0 at the flume and pumped table, respectively) were lower than striped bass. While this pattern was reversed for post yolk-sac larvae (Table 6-18), multiway contingency analysis demonstrated no significant relationship between initial survival and the collection gear used (Appendix Table N-1). Clupeids collected in the flume exhibited higher survival (0.61) than in the pumped table (0.53) in 1979 and 1975 through 1977 (0.35-0.54). During the regular sampling season, bay anchovy survival was 0.04 and 0.14 in the pumped table and flume, respectively. Additional studies during the period of peak anchovy abundance (23 July -

TABLE 6-17 TOTAL NUMBER OF EACH TAXON AND LIFE STAGE COLLECTED FOR SURVIVAL DETERMINATIONS AT THE BOWLINE POINT PLANT, UNIT 1, 1979

	Pumped Larval Table						Plankton Sampling Flume					
	Intake			Discharge			Intake			Diffuser		
Taxon	YSL	PYSL	JUV	YSL	PYSL	JUV	YSL	PYSL	JUV	YSL	PYSL	JUV
White perch	7	136	0	13	112	0	9	69	0	19	79	0
Bay anchovy	1	144	0	0	51	0	0	37	0	0	38	0
Striped bass	6	31	0	19	104	1	7	46	1	11	51	0
Clupeids(a)	0	44	0	0	52	0	0	17	0	0	39	0
Silverside	0	1	0	3	15	0	0	2	0	1	5	0
Minnows and carp	0	0	0	2	7	0	6	4	0	0	2	0
Rainbow smelt	0	2	0	0	3	0	0	0	0	0	2	0
Sunfish	0	1	0	2	2	0	0	1	0	0	2	0
American shad	0	1	0	0	0	0	0	1	0	0	1	0
Tessellated darter	0	0	0	0	0	0	0	0	0	0	0	1
Killifish	0	0	0	0	1	0	0	0	0	0	0	0

(a) Includes *Alosa* spp. and Clupeids, which could not be identified to a primary taxonomic level.
Note: PYSL = post yolk-sac larvae; YSL = yolk-sac larvae; JUV = juveniles.

TABLE 6-18 (CONT.)

		Yolk-Sac Larvae				Post Yolk-Sac Larvae				Juveniles			
			Proportion Alive[(a)]				Proportion Alive				Proportion Alive		
Taxon	Station	No. of Fish	Initial	24-Hour	96-Hour	No. of Fish	Initial	24-Hour	96-Hour	No. of Fish	Initial	24-Hour	96-Hour
Cyprinidae	I_1P	0	--	--	--	0	--	--	--	0	--	--	--
	I_1R	6	0	0	0	4	0.500 ± 0.250	0.500 ± 0.250	0.500 ± 0.250	0	--	--	--
	D_1P	2	0	0	0	7	0.571 ± 0.187	0.571 ± 0.187	0.571 ± 0.187	0	--	--	--
	D_1D	0	--	--	--	2	1.000	1.000	0.500 ± 0.354	0	--	--	--
Rainbow smelt	I_1P	0	--	--	--	2	1.000	0.500 ± 0.354	0.500 ± 0.354	0	--	--	--
	I_1R	0	--	--	--	0	--	--	--	0	--	--	--
	D_1P	0	--	--	--	3	0.667 ± 0.272	0	0	0	--	--	--
	D_1D	0	--	--	--	2	0.500 ± 0.354	0	0	0	--	--	--
Sunfish	I_1P	0	--	--	--	1	0	0	0	0	--	--	--
	I_1R	0	--	--	--	1	0	0	0	0	--	--	--
	D_1P	2	0.500 ± 0.354	0.500 ± 0.354	0	2	0	0	0	0	--	--	--
	D_1D	0	--	--	--	2	1.000	1.000	0	0	--	--	--
American shad	I_1P	0	--	--	--	1	0	0	0	0	--	--	--
	I_1R	0	--	--	--	1	1.000	0	0	0	--	--	--
	D_1P	0	--	--	--	0	--	--	--	0	--	--	--
	D_1D	0	--	--	--	1	0	0	0	0	--	--	--
Tessellated darter	I_1P	0	--	--	--	0	--	--	--	0	--	--	--
	I_1R	0	--	--	--	0	--	--	--	0	--	--	--
	D_1P	0	--	--	--	0	--	--	--	0	--	--	--
	D_1D	0	--	--	--	0	--	--	--	0	1.000	1.000	1.000
Killifish	I_1P	0	--	--	--	0	--	--	--	0	--	--	--
	I_1R	0	--	--	--	0	--	--	--	0	--	--	--
	D_1P	0	--	--	--	1	1.000	1.000	1.000	0	--	--	--
	D_1D	0	--	--	--	0	--	--	--	0	--	--	--

TABLE 6-18 INITIAL, 24-HOUR, AND 96-HOUR SURVIVAL OF EACH TAXON AND LIFE STAGE COLLECTED AT THE BOWLINE POINT PLANT, 1979

		Yolk-Sac Larvae				Post Yolk-Sac Larvae				Juveniles			
		No. of Fish	Proportion Alive[(a)]			No. of Fish	Proportion Alive			No. of Fish	Proportion Alive		
Taxon	Station[(b)]		Initial	24-Hour	96-Hour		Initial	24-Hour	96-Hour		Initial	24-Hour	96-Hour
Striped bass	I_1P	6	0.833 ± 0.152[(c)]	0.833 ± 0.152	0.333 ± 0.192	31	0.710 ± 0.082	0.613 ± 0.087	0.484 ± 0.090	0	--	--	--
	I_1R	7	1.000	0.857 ± 0.132	0.714 ± 0.171	46	0.630 ± 0.071	0.500 ± 0.074	0.435 ± 0.073	1	1.000	1.000	1.000
	D_1P	19	0.632 ± 0.111	0.526 ± 0.115	0.211 ± 0.094	104	0.413 ± 0.048	0.250 ± 0.042	0.202 ± 0.039	1	1.000	1.000	1.000
	D_1D	11	0.636 ± 0.145	0.364 ± 0.145	0.182 ± 0.116	51	0.353 ± 0.067	0.112 ± 0.045	0.078 ± 0.038	0	--	--	--
White perch	I_1P	7	0	0	0	136	0.632 ± 0.041	0.390 ± 0.042	0.206 ± 0.035	0	--	--	--
	I_1R	9	0.111 ± 0.105	0.111 ± 0.105	0	69	0.391 ± 0.059	0.275 ± 0.054	0.159 ± 0.044	0	--	--	--
	D_1P	13	0.077 ± 0.074	0	0	112	0.259 ± 0.041	0.116 ± 0.030	0.054 ± 0.021	0	--	--	--
	D_1D	19	0.368 ± 0.111	0.053 ± 0.051	0	79	0.354 ± 0.054	0.127 ± 0.037	0.076 ± 0.030	0	--	--	--
Morone spp.	I_1P	0	--	--	--	3	0.667 ± 0.272	0.667 ± 0.272	0.333 ± 0.272	0	--	--	--
	I_1R	0	--	--	--	1	0	0	0	0	--	--	--
	D_1P	0	--	--	--	8	0.125 ± 0.117	0.125 ± 0.117	0	0	--	--	--
	D_1D	1	0	0	0	1	0	0	0	0	--	--	--
Bay anchovy	I_1P	1	0	0	0	144	0.035 ± 0.015	0	0	0	--	--	--
	I_1R	0	--	--	--	37	0.135 ± 0.056	0	0	0	--	--	--
	D_1P	0	--	--	--	51	0.039 ± 0.027	0	0	0	--	--	--
	D_1D	0	--	--	--	38	0	0	0	0	--	--	--
	I_1R[(e)]	0	--	--	--	92	0.261 ± 0.046	0.109 ± 0.032	0.054 ± 0.024	0	--	--	--
Clupeids[(d)]	I_1P	0	--	--	--	45	0.533 ± 0.074	0.022 ± 0.022	0.022 ± 0.022	0	--	--	--
	I_1R	0	--	--	--	18	0.611 ± 0.155	0	0	0	--	--	--
	D_1P	0	--	--	--	52	0.308 ± 0.064	0	0	0	--	--	--
	D_1D	0	--	--	--	40	0.300 ± 0.072	0.025 ± 0.025	0.025 ± 0.025	0	--	--	--
Silverside	I_1P	0	--	--	--	1	0	0	0	0	--	--	--
	I_1R	0	--	--	--	2	0.500 ± 0.354	0	0	0	--	--	--
	D_1P	3	0.333 ± 0.272	0	0	15	0.133 ± 0.088	0	0	0	--	--	--
	D_1D	1	0	0	0	5	0.200 ± 0.179	0	0	0	--	--	--

(a) Proportion alive = (number live + number stunned)/total number of organisms collected.

(b) I_1P = pumped larval table (intake)
I_1R = rear draw plankton sampling flume
D_1P = pumped larval table (discharge)
D_1D = pumpless plankton sampling flume (diffuser).

(c) ±1 standard error.

(d) Includes *Alosa* spp., Alosa sapidissima and Clupeidae.

(e) Special study conducted in Bowline Pond near intake structure between 23 July and 13 August.

*

13 August) increased survival of anchovy collected with the flume to 0.23, a significant ($\alpha = 0.05$) increase from that observed with the pumped larval table between 1975 and 1979.

The most abundant taxa generally exhibited a reduction in initial survival at the discharge (Table 6-18). Differences between intake and discharge survival were significant ($\alpha = 0.05$) for white perch and striped bass post yolk-sac larvae (Table N-1). The significant interaction among gear, station and survival for white perch results from the much larger decrease in survival between the intake and standpipe than observed between the intake and diffuser. Survival of white perch yolk-sac larvae was higher at the standpipe and diffuser than at the respective intake stations; however, intake abundance was low and experimental variability may account for this discrepancy. It also is worth noting that the 0.368 survival proportion at the diffuser represents the first time that yolk-sac white perch have been collected alive during the 5-year study at the Bowline Point plant.

It is likely that estimates of initial survival for striped bass and possibly white perch are underestimated as a result of the loss of or inability to identify organisms during the long-term latent effects studies which were classified at alive through 96 hours:

Station	Nos. Organisms Not Positively Identified
Intake (pumped)	21
Intake (pumpless)	2
Discharge (standpipe)	12
Discharge (diffuser)	0

The effect of these unidentified organisms on initial survival estimates would be greatest for striped bass at the pumped intake table and the discharge standpipe, where the number of identified fish was lowest.

6.3.3.1.3 Evaluation of Entrainment Latent Effects on Survival

Organisms which initially survive entrainment may subsequently die as a result of the stress of entrainment, collection, or handling. Comparison of the survival curves and mortality rates at the intake (sampling stress) and discharge (sampling and entrainment stress) provides information on the duration and magnitude of the latent effects of entrainment. During 1979, survival decreased sharply in the first 24 hours following collection for striped bass and white perch post yolk-sac larvae at the intake and the discharge standpipe and diffuser (Figure 6-35, Appendix Tables K-1 to K-3). Multiway contingency analyses indicate that differences between intake and discharge normalized survival values at 24 hours were significant (Table N-2). The survival curves (Figure 6-35) level out after 24 hours, and contingency analysis (Table N-3) of the survival rates between each time interval support the observation that survival rates between 24 and 96 hours are not significantly different ($\alpha = 0.05$) between intake and discharge stations. While the mortality rates for white perch increase after 48 hours (test for time x survival independence was significant at $\alpha = 0.05$), the rates were independent of station (intake vs. discharge). It can therefore be concluded that differences

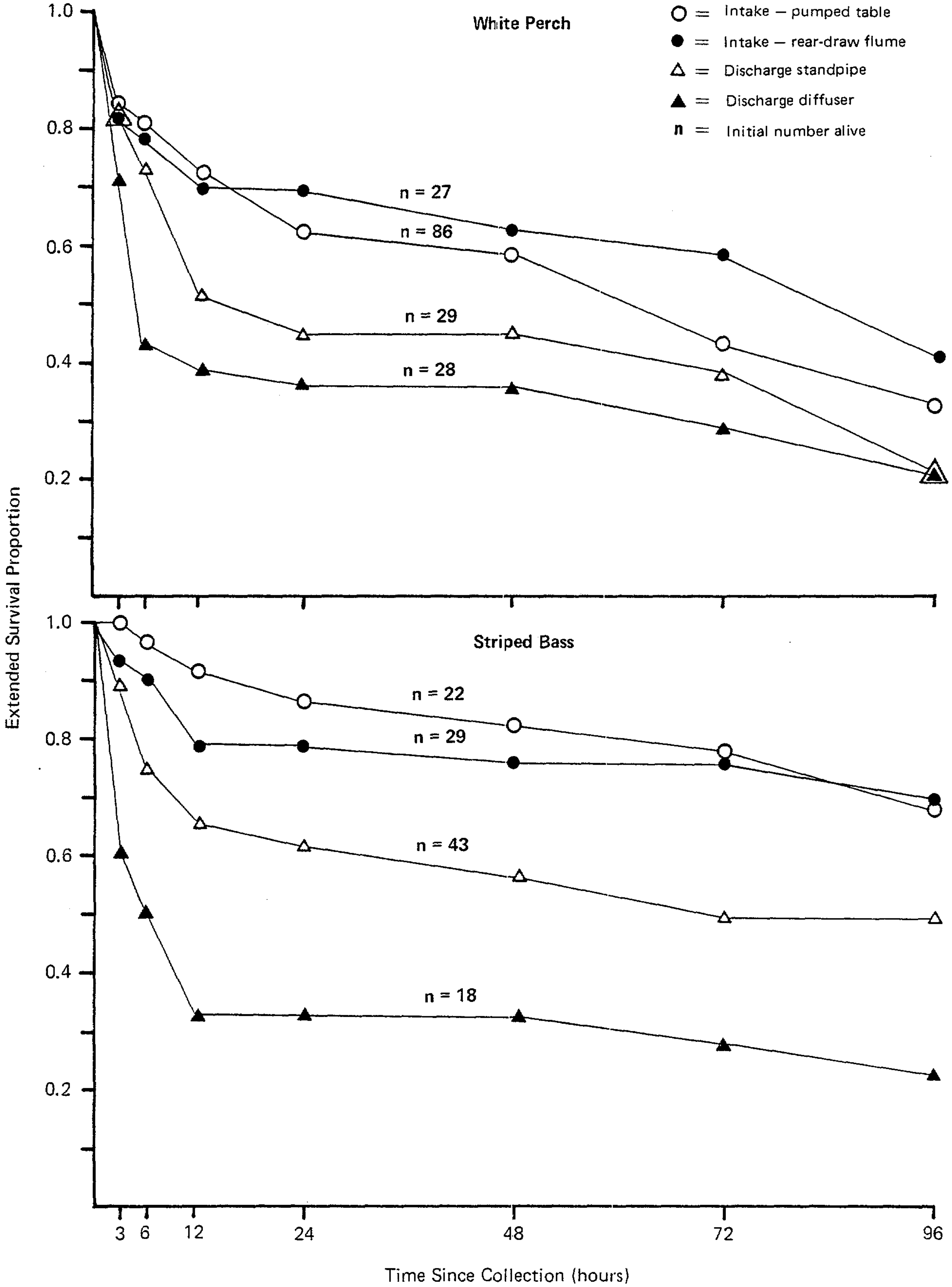


Figure 6-35. Normalized extended survival of white perch and striped bass post yolk-sac larvae collected during entrainment survival studies at the Bowline Point plant, 1979.

in mortality rates during the first 24 hours following entrainment may result in significantly lower survival at the discharge than at the intake.

Mortality observed from 24 to 96 hours is most likely the result of holding stresses and the natural mortality rate for the population. Estimates of the instantaneous daily rate of mortality for Hudson River striped bass in length groups similar to entrained fish (6-15 mm) have ranged from 0.14 to 0.31 (TI 1980a). Although fish held for entrainment studies are not subject to predation, many other sources of mortality are similar to those of river populations and the daily mortality rates of entrained fish are comparable to river estimates:

Observation Interval	Intake	Discharge
3-24 hours	0.03-0.11	0.12-0.27
24-96 hours	0.03-0.17	0.07-0.17

Mortality in samples held for 14 days (Appendix Table K-4) remained at a low rate, which was similar to that observed between 24 and 96 hours. There was no evidence of increased mortality related to sublethal entrainment stress beyond the normal 96-hour observation period.

Since the mortality rates remain constant after 24 hours, it appears that any latent entrainment effects that may occur are fully manifest during the first 24 hours following entrainment. Therefore, analyses using non-normalized (based on the total number collected initially) 24-hour survival will account for both immediate and latent entrainment effects. All subsequent analyses of factors influencing entrainment survival will be presented in terms of initial and 24-hour survival.

The two collection systems used during 1979 produced similar survival curves and no apparent differences in latent survival (Figure 6-35). Survival was slightly higher with the pumped larval table during the first 24 hours, but the pattern was reversed by 96 hours for both striped bass and white perch post yolk-sac larvae. Survival at 24 hours with the two intake collection systems was independent of the gear (Table N-2). Although the two gear have unique benefits for sampling under different field situations, the survival data generated by the two gear appear to be comparable.

Few live individuals from other taxa or life stages were collected during 1979 (Table K-1), and extended survival curves are variable as a result of low sample size and its effect on observed mortality rates. Survival through 24 hours for Clupeids was 0.04 and 0.08 at the intake and diffuser, but no further mortality occurred through 96 hours. Yolk-sac striped bass survival was relatively high at 24 hours (1.00-0.57) and declined to a range of from 0.29 to 0.71 at 96 hours.

6.3.3.1.4 Incidence of Damage to Ichthyoplankton Collected at the Intake, Discharge, and Diffuser

For the purposes of this section, ichthyoplankton are classified into one of three taxonomic levels: primary, secondary, or unidentifiable because of damage. The primary taxonomic level was the lowest grouping to which the ichthyoplankton were routinely identified. Those specimens not reliably identifiable to the primary level because of damage incurred prior to or during entrainment, collection, or handling were identified by recognizable identification characteristics to a secondary level. For example, both striped bass and white perch are of the genus Morone. If an ichthyoplankter from this genus was damaged such that it could not be identified as either species, it was classified as Morone spp., the secondary level of identification. The "unidentifiable" level was composed of ichthyoplankton damaged to the extent that they could not be identified to any primary or secondary level. Also, any ichthyoplankton in good condition and not identifiable by laboratory personnel using available literature and reference collections was classified as "unknown."

For assessment of through-plant damage, all ichthyoplankton initially alive were assumed to be identifiable to the primary level (i.e., having sustained no major morphological damage such that identification would not be possible). This was done because in some instances organisms initially alive were actually classified to the secondary or unidentifiable taxonomic level because important morphological characteristics had been obscured by deterioration during the 96-hour holding period.

Comparison of damage levels at the intake and discharge provides no evidence of elevated levels of damage induced by the plant following entrainment of ichthyoplankton. The incidence of damage was not significantly different ($\alpha = 0.05$) between the intake stations and the associated discharge stations (Table 6-19).

Greater than 93 percent of all collected ichthyoplankton were identifiable to a primary level at each of the four stations. Damage levels with the pump larval tables were lower than in 1978 and slightly higher than in 1977 (Tables 6-20 and 6-21).

The two types of collection gear (pumped larval tables and plankton sampling flumes) result in significantly different levels of damage. The rear-draw intake sampling flume permitted identification of 98 percent of the organisms to the primary level, while 93.8 percent were identifiable to the same level from the pumped table. The higher level of damage in the pumped system may be related to the use of the pump inline to collect organisms or the proximity of the filtration screens to the inlet of the sampling gear (Figures 6-27 and 6-28).

6.3.3.1.5 Mechanical and Thermal Effects of Entrainment

In the absence of biocides, the two major sources of entrainment mortality are mechanical and thermal stress. The effects of thermal exposure on the most abundant entrained ichthyoplankton have been estimated in controlled laboratory studies (EA 1978b, 1979b). These independent estimates of thermal mortality can be combined with field estimates of mechanical effects to provide an overall estimate of entrainment mortality factors (fc) for historic or projected modes of plant operation (Jinks et al. 1978). Some mechanical stresses that may result in mortality during entrainment are rapid reduction in pressure (NYU 1975), shear forces (Morgan et al. 1973, 1976; Morgan 1974), and abrasion. During most of the 1979 survival sampling program, the Bowline Point plant was not generating power. Consequently, since entrained organisms

TABLE 6-19 PERCENT COMPOSITION OF ICHTHYOPLANKTON COLLECTED AT THE BOWLINE POINT PLANT WITH THE PLANKTON SAMPLING SYSTEMS AND CLASSIFIED TO VARIOUS IDENTIFICATION LEVELS DURING STRIPED BASS SEASON, 1979

			Percent of Total Collected 1-27 June			
Level of Identification	Condition	Taxa	$I_1P^{(a)}$ (403)*	$I_1R^{(b)}$ (205)	$D_1P^{(a)}$ (407)	$D_1D^{(c)}$ (258)
Undamaged						
Primary	Alive + dead	Striped bass and white perch	44.7	64.4	61.2	62.0
		Bay anchovy	33.3	18.0	11.5	13.6
		Alosa spp.	10.4	7.8	11.5	15.1
		All other species	1.2	6.8	8.6	5.4
Secondary	Alive	Clupeidae	0.5	0.0	0.2	0.0
		Morone spp.	1.7	0.5	0.5	0.0
		Engraulidae	0.2	0.0	0.0	0.0
		Unidentifiable	1.7	0.5	0.7	0.4
	Alive + dead	Total	93.8	98.0	94.3	96.5
Damaged						
Secondary	Dead		0.0	0.5	1.0	0.0
		Morone spp.	0.7	0.5	2.2	1.6
		Engraulidae	2.5	0.0	1.0	1.2
		Unidentifiable	3.0	1.0	1.5	0.7
		Total	6.2	2.0	5.7	3.5

(a) Pumped larval table.
(b) Rear-draw plankton sampling flume.
(c) Pumpless plankton sampling flume.

Note: *Number in parentheses is number of organisms collected at the station.

TABLE 6-20 PERCENT COMPOSITION OF ICTHYOPLANKTON COLLECTED AT THE BOWLINE POINT PLANT WITH THE TWO-SCREEN LARVAL TABLE AND CLASSIFIED TO VARIOUS IDENTIFICATION LEVELS DURING ATLANTIC TOMCOD, STRIPED BASS, AND BAY ANCHOVY SEASONS, 1978

Level of Identification	Condition	Taxa	Percent of Total Collected							
			(13 MAR - 21 JUL)		(13 MAR - 16 MAY)		(30 MAY - 30 JUN)		(9-21 JUL)	
			Intake (1,715)*	Discharge (2,146)	Intake (86)	Discharge (163)	Intake (1,268)	Discharge (1,376)	Intake (361)	Discharge (607)
Undamaged										
Primary	Alive + dead	Atlantic tomcod	4.1	3.7	75.5	49.2	0.5	0	0	0
		Striped bass and white perch	52.0	42.7	1.2	1.2	70.3	66.5	0	0
		Bay anchovy	19.2	27.1	0	0	0.4	1.8	90.0	91.6
		Alosa spp.	2.7	10.8	0	6.7	3.6	16.0	0	0
		All other species	2.9	6.6	7.0	33.1	3.5	6.1	0	0.7
Secondary	Alive	Clupeidae	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0
		Morone spp.	1.3	0.8	0.0	0.0	1.8	1.3	0.0	0.0
		Engraulidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Unidentifiable	0.5	0.3	0.0	0.6	0.7	0.4	0.0	0.0
		Unknown	0.2	0.2	4.7	2.5	0.0	0.0	0.0	0.0
	Alive + dead	Total	83.0	92.2(a)	88.4	93.3	80.9	92.2(a)	90.0	92.3
Damaged										
Secondary	Dead	Clupeidae	0.4	0.1	0.0	0.0	0.5	0.1	0.3	0.0
		Morone spp.	9.6	2.7	0.0	0.0	13.0	4.2	0.0	0.0
		Engraulidae	2.0	2.0	0.0	0.0	0.2	0.2	9.1	6.6
		Unidentifiable	4.7	2.9	11.6	6.7	5.4	3.2	0.6	1.2
		Unknown	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0
		Total	16.8	7.7	11.6	6.7	19.2	7.7	10.0	7.8

(a) Indicates proportion of organisms identifiable to the primary level was significantly higher at the discharge for a one-tailed test of differences between two proportions (α = 0.05).

Note: * - Number in parenthesis is number of organisms collected at the station.

TABLE 6-21 PERCENT COMPOSITION OF ICHTHYOPLANKTON COLLECTED AT THE BOWLINE POINT PLANT WITH THE TWO-SCREEN LARVAL TABLE AND CLASSIFIED TO VARIOUS IDENTIFICATION LEVELS DURING STRIPED BASS AND BAY ANCHOVY SEASONS, 1977

			Percent of Total Collected					
			(1 JUN - 15 JUL)		(1-26 JUN)		(27 JUN - 15 JUL)	
Level of Identification	Condition	Taxa	Intake (964)*	Discharge (2,283)	Intake (340)	Discharge (641)	Intake (624)	Discharge (1,642)
Undamaged								
Primary	Alive + dead	Striped bass and white perch	28.0	25.8	75.3	78.6	2.2	5.1
		Clupeidae	3.2	1.1	9.1	3.6	0	0.1
		Bay anchovy	64.3	67.1	10.6	8.1	93.6	90.2
		All other species	2.9	3.5	2.1	5.6	3.4	2.7
Secondary	Alive	*Morone* spp.	0.3	0.0	0.9	0.2	0.0	0.0
		Clupeiformes	0.0	0.0	0.0	0.0	0.0	0.0
		Unidentifiable	0.0	0.0	0.0	0.0	0.0	0.0
		Unknown	0.0	0.1	0.0	0.3	0.0	0.0
	Alive + dead	Total	98.7	97.6	98.0	96.4	99.2	98.1
Damaged								
Secondary	Dead	*Morone* spp.	0.1	0.9	0.3	2.7	0.0	0.2
		Clupeiformes	0.6	0.0	1.2	0.0	0.3	0.0
		Unidentifiable	0.3	1.3	0.0	0.5	0.5	1.6
		Unknown	0.2	0.1	0.6	0.5	0.0	0.0
		Total	1.1	2.3	2.1	2.7	0.8	1.8

---

* Number in parenthesis is number of organisms collected at the station.

were generally not exposed to thermal increases, much of the data can be used to estimate mechanical effects in the absence of any thermal discharge (Table 6-22). A second estimate of mechanical effects can be made from survival data for organisms entrained from 18 to 22 June when the plant was in a generating mode and discharge temperatures were below the lab-predicted lethal thermal threshold. Survival of organisms entrained at discharge temperatures less than 30 C were used for this second estimate (Table 6-22). This second method may overestimate entrainment mechanical mortality if the assumed independence of sublethal thermal and mechanical or sampling stress is not valid.

As would be expected at the intake, where only sampling stresses are encountered, no significant differences were observed between the two plant operating modes (Table N-4). For this reason, entrainment survival estimates were made using intake survival data pooled across plant generating modes. The collection gear was found to have a significant effect on initial intake survival for white perch (Table N-4). This gear effect was the result of low survival (19 percent) of 3-6 mm larvae collected in the flume relative to that observed in the pumped larval table (55 percent) and compared to 6-9 mm larvae (59-63 percent) from both gear (Table 6-23). Because the two collection systems may have a differential effect on survival of some organisms, intake samples were not pooled across collection gear types.

Multiway contingency analysis demonstrated a significant reduction in survival at the discharge during periods of sublethal thermal exposure only for striped bass post yolk-sac larvae collected at the standpipe (Table N-5). The difference observed for striped bass may not be directly related to sublethal thermal stress, but rather to differences in the length distribution of striped bass collected during the period of thermal discharge (18-22 June) compared to the rest of the sampling season. A high proportion of 9-12 mm larvae were collected at the discharge standpipe relative to the other three stations from 18-22 June (Appendix J-1), and this length group exhibited lower survival (13 percent) than the more abundant 6-9 mm fish (54 percent). Survival of white perch initially and both striped bass and white perch at 24 hours exhibited no significant relationship with plant operation. Although differences were not significant, survival with the circulating pumps operating with no thermal discharge was slightly higher than with a thermal discharge below the lethal thermal threshold. On the basis of these results, it is reasonable to conclude that there is no significant interaction between sublethal thermal stress and mechanical stress. Consequently, estimates of survival of mechanical entrainment stress (Table 6-24) can be made based on all survival data collected below discharge temperatures of 30 C.

Entrainment survival estimates for the most abundant taxa were not significantly ($\alpha = 0.05$) less at the diffuser compared to the discharge standpipe. Striped bass survival was slightly higher at the discharge, but white perch survival was higher at the diffuser (Table 6-24). The apparent increase in white perch survival between the standpipe and the diffuser is an artifact of the extremely low survival observed for 3-6 mm larvae in the intake flume. Since intake survival for this group of larvae was lower (18.9 percent) than observed at the diffuser (31 percent), it would appear that an as yet undetermined gear effect (which increased sampling stress) was operating at the intake flume. Whatever the source of this stress, similar effects were not observed at the other stations or for other species. Consequently, the best

TABLE 6-22 SURVIVAL OF ICHTHYOPLANKTON AT THE INTAKE, UNIT 1 DISCHARGE AND DIFFUSER OF THE BOWLINE POINT PLANT AS A FUNCTION OF TEMPERATURE EXPOSURE, 1979

			Yolk-Sac Larvae			Post Yolk-Sac Larvae			Juvenile		
Species	Station	Temperature (C)	No. of Fish	P_s--Init.(a)	P_s--24 hr.(b)	No. of Fish	P_s--Init.	P_s--24 Hr.	No. of Fish	P_s--Init.	P_s--24 Hr.
Striped bass	Intake pumped table	All samples	6	0.833	0.833	31	0.710	0.613	0	--	--
		NT(c)	4	0.750	0.750	27	0.741	0.667	0	--	--
	Intake flume	All samples	7	1.000	0.857	46	0.630	0.500	1	1.000	1.000
		NT	2	1.000	1.000	32	0.563	0.406	1	1.000	1.000
	Discharge standpipe	20.0-29.9	2	0.000	0.000	42	0.262	0.143	0	--	--
		30.0-32.9	2	0.000	0.000	3	0.000	0.000	0	--	--
		33.0-35.9	0	--	--	0	--	--	0	--	--
		NT	15	0.800	0.667	59	0.542	0.339	1	1.000	1.000
	Discharge Diffuser	20.0-29.9	3	0.333	0.000	23	0.348	0.174	0	--	--
		30.0-32.9	1	0.000	0.000	0	--	--	0	--	--
		33.0-35.9	1	1.000	1.000	0	--	--	0	--	--
		NT	6	0.833	0.500	28	0.357	0.071	0	--	--
White perch	Intake pumped table	All samples	7	0.000	0.000	136	0.632	0.390	0	--	--
		NT	2	0.000	0.000	105	0.676	0.429	0	--	--
	Intake flume	All samples	9	0.111	0.111	69	0.391	0.275	0	--	--
		NT	4	0.000	0.000	48	0.313	0.229	0	--	--
	Discharge standpipe	20.0-29.9	5	0.000	0.000	24	0.125	0.125	0	--	--
		30.0-32.9	0	--	--	2	0.000	0.000	0	--	--
		33.0-35.9	0	--	--	4	0.000	0.000	0	--	--
		NT	8	0.125	0.000	82	0.317	0.122	0	--	--
	Discharge Diffuser	20.0-29.9	3	0.333	0.333	12	0.333	0.167	0	--	--
		30.0-32.9	0	--	--	0	--	--	0	--	--
		33.0-35.9	0	--	--	3	0.000	0.000	0	--	--
		NT	16	0.375	0.000	64	0.375	0.125	0	--	--
Clupeids	Intake pumped table	All samples	0	--	--	45	0.533	0.022	0	--	--
		NT	0	--	--	45	0.533	0.022	0	--	--
	Intake flume	All samples	0	--	--	18	0.611	0.000	0	--	--
		NT	0	--	--	16	0.563	0.000	0	--	--
	Discharge standpipe	20.0-29.9	0	--	--	6	0.167	0.000	0	--	--
		30.0-32.9	0	--	--	0	--	--	0	--	--
		33.0-35.9	0	--	--	0	--	--	0	--	--
		NT	0	--	--	46	0.326	0.000	0	--	--
	Discharge Diffuser	20.0-29.9	0	--	--	2	0.500	0.000	0	--	--
		30.0-32.9	0	--	--	0	--	--	0	--	--
		33.0-35.9	0	--	--	0	--	--	0	--	--
		NT	0	--	--	38	0.289	0.026	0	--	--

(a) P_s--Init. = initial proportion surviving.
(b) P_s--24 hr. = 24 hr proportion surviving.
(c) NT = No thermal addition.

TABLE 6-22 (CONT.)

			Yolk-Sac Larvae			Post Yolk-Sac Larvae			Juvenile		
Species	Station	Temperature (C)	No. of Fish	P_s--Init.(a)	P_s--24 hr.(b)	No. of Fish	P_s--Init.	P_s--24 Hr.	No. of Fish	P_s--Init.	P_s--24 Hr.
Bay anchovies	Intake pumped table	All samples	1	0.000	0.000	144	0.035	0.000	0	--	--
		NT	1	0.000	0.000	142	0.035	0.000	0	--	--
	Intake flume	All samples	0	--	--	37	0.135	0.000	0	--	--
		NT	0	--	--	33	0.152	0.000	0	--	--
	Discharge standpipe	20.0-29.9	0	--	--	1	0.000	0.000	0	--	--
		30.0-32.9	0	--	--	0	--	--	0	--	--
		33.0-35.9	0	--	--	0	--	--	0	--	--
		NT	0	--	--	50	0.040	0.000	0	--	--
	Discharge Diffuser	20.0-29.9	0	--	--	3	0.000	0.000	0	--	--
		30.0-32.9	0	--	--	0	--	--	0	--	--
		33.0-35.9	0	--	--	0	--	--	0	--	--
		NT	0	--	--	35	0.000	0.000	0	--	--

TABLE 6-23 INITIAL SURVIVAL OF STRIPED BASS AND WHITE PERCH COLLECTED AT THE BOWLINE POINT PLANT INTAKE, DISCHARGE STANDPIPE, AND DIFFUSER AS A FUNCTION OF LENGTH, 1979

Striped Bass

	Intake - Flume		Intake - Pumped Table		Unit 1 Discharge		Unit 1 Diffuser	
Length (mm)	No. of Fish Measured	P_s(a)	No. of Fish Measured	P_s	No. of Fish Measured	P_s	No. of Fish Measured	P_s
0.0-2.9	0	--	0	--	0	--	0	--
3.0-5.9	3	0.667 ± 0.272	3	1.000	11	0.364 ± 0.145	2	1.000
6.0-8.9	37	0.701 ± 0.075	25	0.680 ± 0.093	70	0.543 ± 0.060	43	0.372 ± 0.074
9.0-11.9	8	0.375 ± 0.171	1	0.000	30	0.133 ± 0.062	15	0.333 ± 0.122
12.0-14.9	0	--	2	0.500 ± 0.354	3	0.000	1	1.000
15.0-17.9	0	--	0	--	0	--	0	--
18.0-20.9	0	--	0	--	0	--	0	--
21.0-23.9	0	--	0	--	0	--	0	--
24.0-99.9	0	--	0	--	0	--	0	--
Unmeasured	6	1.000	6	1.000	10	1.000	1	1.000

White Perch

	Intake - Flume		Intake - Pumped Table		Unit 1 Discharge		Unit 1 Diffuser	
Length (mm)	No. of Fish Measured	P_s(a)	No. of Fish Measured	P_s	No. of Fish Measured	P_s	No. of Fish Measured	P_s
0.0-2.9	0	--	0	--	0	--	0	--
3.0-5.9	53	0.189 ± 0.054	109	0.550 ± 0.048	102	0.196 ± 0.039	84	0.310 ± 0.050
6.0-8.9	17	0.588 ± 0.119	19	0.632 ± 0.111	13	0.308 ± 0.128	12	0.583 ± 0.142
9.0-11.9	3	1.000	3	0.667 ± 0.272	7	0.571 ± 0.187	1	1.000
12.0-14.9	1	1.000	0	--	0	--	0	--
15.0-17.9	0	--	0	--	0	--	0	--
18.0-20.9	0	--	0	--	0	--	0	--
21.0-23.9	0	--	0	--	0	--	0	--
24.0-99.9	0	--	0	--	0	--	0	--
Unmeasured	4	1.000	12	1.000	3	0.667 ± 0.272	1	1.000

(a) P_s = initial proportion alive: (no. live + no. stunned/no. live + no. stunned + no. dead).

(b) ±1 standard error.

TABLE 6-24 ESTIMATES OF POST YOLK-SAC ENTRAINMENT SURVIVAL IN THE ABSENCE OF THERMAL STRESS (Mechanical Effects Only) AT THE BOWLINE POINT PLANT, 1979

Species	Observation	S_e(%)[(a)] Standpipe	S_e(%)[(a)] Diffuser
Striped bass	Initial	60.0 ± 9.8	56.0 ± 12.4
	24 hr.	41.9 ± 11.4	23.6 ± 9.7
White perch	Initial	43.3 ± 7.4	94.1 ± 20.0 (36.8 ± 5.5)[(b)]
	24 hr.	31.5 ± 3.4	48.0 ± 16.9 (32.2 ± 3.9)[(b)]
Clupeids	Initial	57.7 ± 14.5	30.0 ± 13.1
	24 hr.	--	--

(a) S_e = entrainment survival (discharge survival/intake survival) ±1 standard error.

(b) Estimates of entrainment survival (in parenthesis) at the diffuser for white perch are based on uncorrected diffuser survival because apparent differential gear effects preclude use of intake flume data to calculate S_e.

estimate of entrainment survival at the diffuser for white perch post yolk-sac larvae is the observed diffuser survival uncorrected for sampling mortality. It appears that the additional distance traveled in the discharge pipe and passage through the diffuser does not significantly increase the rate of mortality associated with mechanical stress.

Comparison of initial and 24-hour entrainment survival estimates shows a reduction in survival of approximately from 12 to 45 percent during the first 24 hours following entrainment, which may be associated with the latent effects of entrainment. No 24-hour entrainment survival estimate could be calculated for clupeids since none survived through 24 hours of either the intake rear-draw flume or the discharge standpipe.

While estimates of entrainment survival for post yolk-sac larvae are generally lower than in previous years, this observation may be a result of the sampling schedule. During 1979, sampling ended in late June and few larvae in excess of 9 mm were collected. Studies between 1975 and 1978 showed that survival increased with length and because of the longer sampling season, larvae greater than 9 mm composed a significant portion of the post yolk-sac life stage. Therefore, comparison of annual S_e for data pooled by life stage can be misleading.

The apparent decrease in survival with length observed for striped bass may be a sampling artifact, since live larvae held past 96 hours were not measured and many other organisms which were alive at 96 hours are missing from the analysis because positive identification was prevented by decomposition or organisms were lost during extended holding as a result of predation or cannibalism:

	Pumped Intake	Pumpless Intake	Standpipe	Diffuser
Striped bass (PYS)	6	7	7	1
Morone spp.	3	0	1	0
Decomposed	6	1	3	0
Missing (after 96 hours)	12	1	8	0

Preliminary field identification at 96 hours indicated that most of these organisms were probably *Morone*. Therefore, if a significant proportion of these fish were striped bass and if survival increases with length (as in previous years), initial survival may be progressively underestimated as length increases.

6.3.3.2 Direct Release Studies with Hatchery-reared Striped Bass

6.3.3.2.1 Initial Survival During Direct Release

Initial survival of hatchery-reared striped bass varied by life stage, sampling station, and sampling gear (Table 6-25). Survival was lowest for yolk-sac larvae, higher for post yolk-sac larvae, and generally highest for eggs. Survival proportions for hatchery-reared striped bass eggs tested in direct release and associated control experiments varied from 0.341 to 1.000 (Table 6-25). Striped bass yolk-sac larvae, 3 to 5 days old (Table L-1) were

TABLE 6-25 SURVIVAL OF HATCHERY-REARED STRIPED BASS DURING DIRECT RELEASE STUDIES AT THE BOWLINE POINT PLANT, 1979

Life Stage	Dates	Station	Number Collected	Proportion Surviving[a] Initial	Proportion Surviving[a] 24-Hour
Eggs	21,22,24 May	Holding control	122	1.000	0.983
		Intake-pump	146	0.733 ± 0.037[b]	0.603
		Intake-pumpless	159	0.950 ± 0.017	0.912
		Discharge-pump	44	0.341 ± 0.071	0.205 ± 0.061
		Diffuser-pumpless	27	0.778 ± 0.080	0.778 ± 0.080
Yolk sac-larvae	24,25,29 May	Holding control	130	1.000	0.769 ± 0.037
		Intake-pump	193	0.316 ± 0.033	0.176 ± 0.027
		Intake-pumpless	212	0.179 ± 0.026	0.132 ± 0.023
		Discharge-pump	100	0.320 ± 0.047	0.240 ± 0.043
		Diffuser-pumpless	45	0.289 ± 0.068	0.222 ± 0.062
Post yolk-sac larvae	31 May 5,6,12,13,19 20,22,25 June	Holding control	438	1.000	0.808 ± 0.019
		Intake-pump	418	0.596 ± 0.024	0.502 ± 0.024
		Intake-pumpless	389	0.830 ± 0.019	0.712 ± 0.023
		Discharge-pump	534	0.556 ± 0.022	0.498 ± 0.022
		Diffuser-pumpless	122	0.533 ± 0.045	0.475 ± 0.045

(a) Proportion surviving = (no. live + no. stunned/total no. collected) - non-normalized.

(b) ±1 standard error.

apparently more sensitive to stresses associated with entrainment, sampling, and holding, since initial survival proportions for all test groups were lower than those for eggs (Table 6-25). Initial survival proportions for post yolk-sac larvae were substantially higher than for yolk-sac larvae and ranged from 0.533 to 1.000.

Survival of hatchery-reared striped bass eggs was significantly lower, (Table N-6) at the discharge stations, (discharge and diffuser) than at the two intake stations (Table 6-25) and therefore significant entrainment mortality occurs. Significant differences in egg mortality (Table N-6) between the pumped and pumpless sampling gear were observed with much higher survival associated with the pumpless (0.950 and 0.778) system in comparison to the pumped table (0.733 and 0.341). The lack of independence between gear and station, although significant (Table N-6), indicated only that organisms were not randomly distributed among the various combinations of gear and station (Table 6-25).

Initial survival of hatchery-reared striped bass yolk-sac larvae was always low (Table 6-25) but did not significantly differ between the intake and discharge station (Table N-6). In contrast to egg survival, the pumped larval tables had significantly higher survival than the pumpless gear (0.316 versus 0.179 at the intake and 0.320 versus 0.289 at the discharge). As with eggs, the nonrandom distribution of organisms caused a significant interaction (Table N-6) between gear and station, with intake collections always containing more organisms than the discharge collections. No significant gear x station x survival interaction was observed.

All three main factors, gear x station, station x survival, and gear x survival along with the interaction among the three factors were significant ($\alpha = 0.05$) for hatchery-reared striped bass post yolk-sac larvae (Table N-6). Initial survival was higher at the intake than the discharge (Table 6-25) thus indicating significant entrainment induced mortality. The three-factor interaction was probably caused by the shift in relationship of survival between intake stations and discharge stations for the pumped larval table versus plankton sampling flume. The pumpless flume produced much higher (0.830 to 0.596) survival at the intake but slightly lower (0.533 to 0.556) survival at the discharge in comparison to the pumped table. Over 60 percent of the overall significant interaction is attributable to the lack of independence between which gear x station signifies an uneven distribution of organisms along the gear and station combinations (Table 6-25).

In summary, initial survival of hatchery-reared striped bass varied by life stage, sampling station, and sampling gear. Eggs exhibited the highest survival followed by post yolk-sac and yolk-sac larvae. Significantly ($\alpha = 0.05$) higher egg survival occurred at the intake than discharge station and for the pumpless versus the pumped collection methods. No significant difference in survival was noted between the intake and discharge stations but the pumped larval table demonstrated higher survival of yolk-sac larvae. Post yolk-sac larvae survival was higher at the intake than discharge station.

6.3.3.2.2 Latent Effects During Direct Release

Survival of hatchery-reared striped bass determined initially to be alive or stunned was monitored for 96 hours following sample collection to test for the presence of latent effects due to entrainment. Extended survival of hatchery-reared striped bass differed by life stage, sometimes by collection gear, but not by sampling station (Figure 6-36). As with initial survival (Section 6.3.3.2.1), 24-hour survival was lowest for yolk-sac larvae, higher for post yolk-sac larvae, and highest for eggs (Table 6-26). Striped bass yolk-sac larvae were apparently more sensitive to stresses associated with entrainment, sampling, and holding than either eggs or post yolk-sac larvae. The fairly strong decrease in survival between 72 and 96 hours for post yolk-sac larvae may be attributable to starvation or other holding-associated problems.

Extended survival (96-hours) of hatchery-reared striped bass eggs was highly dependent ($\alpha = 0.05$) on the collection gear (Table N-7). All eggs collected hatched or were dead by 96 hours, therefore total hatch at 96 hours was used to evaluate latent effects for eggs. Eggs collected with the pumpless (0.874 at intake and 0.952 at discharge) plankton flume exhibited much higher survival than eggs collected with the pumped (0.804 at intake and 0.600 at discharge) larval tables (Table 6-26) indicating that there is less of a sampling effect on eggs collected in the pumpless system. No significant difference was observed in latent survival between organisms collected at the intake and discharge stations and no significant gear x station x survival interaction was noted.

As observed for wild larvae the sharpest decline in survival occurred prior to 24 hours (Section 6.3.3.1.3). After 24 hours the intake and discharge curves were generally parallel; i.e., the rate of mortality over each 24 hour interval was the same for both intake and discharge stations. No significant ($\alpha = 0.05$) differences in 24-hour survival of yolk-sac larvae were found between the intake or discharge samples collected with either the pumped or pumpless gear (Table N-7). The three-way interaction was not significant and the overall three-way test of independence was also nonsignificant (Table N-7). Survival through 96 hours decreased but both stations, both gear, and even the holding controls decreased at a fairly uniform rate (Figure 6-36).

Twenty-four hour survival of hatchery-reared striped bass post yolk-sac larvae did not significantly ($\alpha = 0.05$) differ between intake and discharge stations or with the method of collection (Table N-7). The gear x station interaction was highly significant but denotes only the nonrandom distribution of organisms collected in various gear and station combinations. There was no significant three-way interaction among gear x station x survival.

Minimal additional mortality beyond that observed by 96 hours was observed in long-term (14-day) survival studies of hatchery-reared striped bass yolk-sac and post yolk-sac larvae (Table 6-27). Limited sample sizes (n = 4 and 22) precluded valid statistical comparisons of survival at the intake and discharge and pump versus pumpless collection gear for yolk-sac larvae. However, discharge samples exhibited a lower survival of post yolk-sac larvae than did intake samples (Table 6-27).

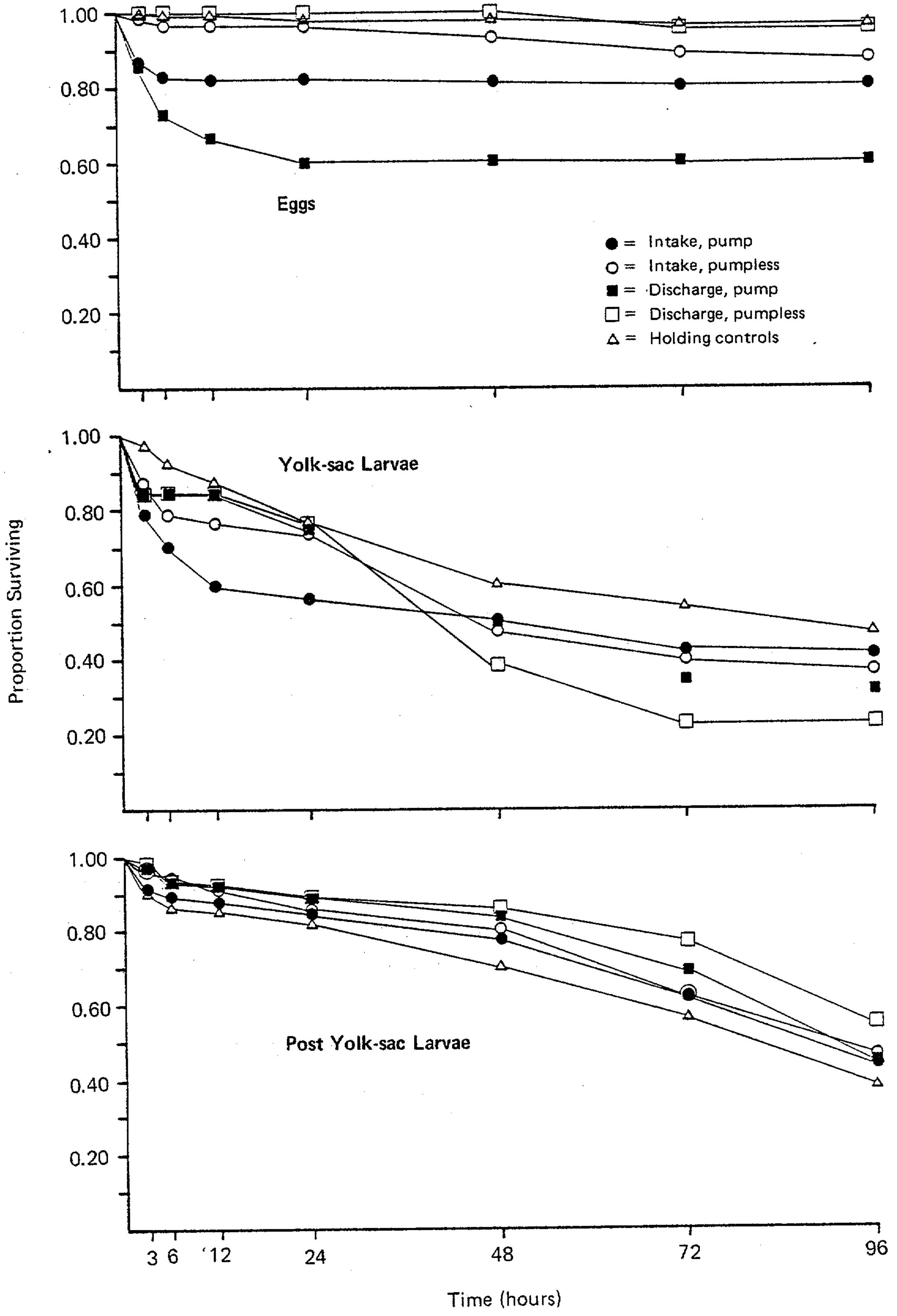


Figure 6-36. Extended survival curves for hatchery-reared striped bass eggs (live and hatched) and larvae collected at the intake and discharge during direct release sampling at the Bowline Point plant, 1979.

TABLE 6-26 EXTENDED SURVIVAL OF EGGS AND LARVAE OF HATCHERY-REARED STRIPED BASS COLLECTED AT THE INTAKE, DISCHARGE STANDPIPE, AND DISCHARGE DIFFUSER DURING DIRECT RELEASE SAMPLING AT THE BOWLINE POINT PLANT, 1979

Life Stage	Station	No. of Organisms(a)	0 hours	3 hours	6 hours	12 hours	24 hours	48 hours	72 hours	96 hours
Eggs	Holding controls	122	1.000	1.000	0.992±0.008(b)	0.992±0.008	0.984±0.011	0.984±0.011	0.967±0.016	0.967±0.016
	Intake--pump	107	1.000	0.869±0.055	0.832±0.021	0.823±0.021	0.822±0.020	0.813±0.020	0.804±0.038	0.804±0.038
	Intake--pumpless	151	1.000	0.987±0.009	0.967±0.015	0.967±0.015	0.960±0.015	0.934±0.018	0.887±0.019	0.874±0.027
	Discharge standpipe--pump	15	1.000	0.867±0.088	0.733±0.114	0.667±0.122	0.600±0.126	0.600±0.126	0.600±0.126	0.600±0.126
	Discharge diffuser--pumpless	21	1.000	1.000	1.000	1.000	1.000	1.000	0.952±0.047	0.952±0.047
Yolk-sac larvae	Holding controls	130	1.000	0.969±0.015	0.923±0.023	0.877±0.029	0.769±0.037	0.600±0.043	0.538±0.044	0.469±0.044
	Intake--pump	61	1.000	0.787±0.052	0.705±0.058	0.607±0.063	0.557±0.064	0.508±0.064	0.426±0.063	0.410±0.063
	Intake--pumpless	38	1.000	0.868±0.055	0.789±0.066	0.763±0.069	0.737±0.071	0.474±0.081	0.395±0.079	0.368±0.078
	Discharge standpipe--pump	32	1.000	0.844±0.064	0.844±0.064	0.844±0.064	0.750±0.077	0.500±0.088	0.344±0.084	0.313±0.082
	Discharge diffuser--pumpless	13	1.000	0.846±0.100	0.846±0.100	0.846±0.100	0.769±0.117	0.385±0.135	0.231±0.117	0.231±0.117
Post yolk-sac larvae	Holding controls	438	1.000	0.900±0.014	0.863±0.016	0.847±0.017	0.808±0.019	0.705±0.022	0.564±0.024	0.379±0.023
	Intake--pump	249	1.000	0.912±0.018	0.896±0.019	0.876±0.021	0.843±0.023	0.775±0.026	0.622±0.029	0.442±0.031
	Intake--pumpless	323	1.000	0.969±0.010	0.944±0.013	0.913±0.016	0.858±0.019	0.799±0.022	0.625±0.027	0.467±0.028
	Discharge standpipe--pump	297	1.000	0.976±0.009	0.939±0.014	0.919±0.016	0.896±0.018	0.838±0.021	0.687±0.027	0.444±0.029
	Discharge diffuser--pumpless	65	1.000	0.938±0.015	0.938±0.030	0.923±0.033	0.892±0.038	0.862±0.043	0.769±0.052	0.554±0.062

(a) Number of organisms indicates number of fish alive (live and stunned) at 0 hours.

(b) ± standard error.

TABLE 6-27 LONG-TERM (14-DAY) SURVIVAL OF HATCHERY-REARED STRIPED BASS DURING DIRECT RELEASE STUDIES AT THE BOWLINE POINT PLANT, 1979

Yolk-Sac Larvae	Holding Control N = 84	Intake Pump N = 42	Intake Pumpless N = 33	Discharge Pump N = 22	Diffuser Pumpless N = 4
96-hour	0.333±0.103	0.405±0.076	0.333±0.082	0.136±0.073	0.750±0.217
5 days	0.333±0.103	0.381±0.071	0.333±0.082	0.136±0.073	0.750±0.217
6 days	0.333±0.103	0.381±0.071	0.333±0.082	0.136±0.073	0.750±0.217
7 days	0.333±0.103	0.357±0.074	0.333±0.082	0.136±0.073	0.750±0.217
8 days	0.310±0.104	0.357±0.074	0.333±0.082	0.136±0.073	0.750±0.217
9 days	0.310±0.104	0.357±0.074	0.333±0.082	0.136±0.073	0.750±0.217
10 days	0.310±0.104	0.357±0.074	0.333±0.082	0.136±0.073	0.750±0.217
11 days	0.310±0.104	0.357±0.074	0.333±0.082	0.091±0.061	0.750±0.217
12 days	0.310±0.104	0.357±0.074	0.333±0.082	0.091±0.061	0.750±0.217
13 days	0.310±0.104	0.357±0.074	0.333±0.082	0.091±0.061	0.750±0.217
14 days	0.310±0.104	0.357±0.074	0.333±0.082	0.091±0.061	0.750±0.217

Post Yolk-Sac Larvae	N = 219	N = 143	N = 187	N = 186	N = 40
96-hour	0.388±0.033	0.483±0.042	0.465±0.036	0.457±0.037	0.450±0.079
5 days	0.288±0.031	0.378±0.041	0.421±0.036	0.360±0.035	0.375±0.077
6 days	0.256±0.029	0.370±0.040	0.374±0.035	0.339±0.035	0.275±0.071
7 days	0.233±0.029	0.364±0.040	0.374±0.035	0.290±0.033	0.250±0.068
8 days	0.205±0.027	0.350±0.040	0.348±0.035	0.220±0.030	0.225±0.066
9 days	0.201±0.027	0.312±0.039	0.348±0.035	0.210±0.030	0.225±0.066
10 days	0.187±0.026	0.312±0.039	0.332±0.034	0.177±0.028	0.225±0.066
11 days	0.187±0.026	0.312±0.039	0.310±0.034	0.167±0.026	0.225±0.066
12 days	0.187±0.026	0.312±0.039	0.310±0.034	0.151±0.026	0.200±0.063
13 days	0.187±0.026	0.312±0.039	0.310±0.034	0.151±0.026	0.175±0.060
14 days	0.187±0.026	0.308±0.039	0.305±0.034	0.145±0.026	0.175±0.060

Any long-term survival study should consider the effects of naturally occurring decreases in the population. The observed mortality rates for these long-term (14-day) studies were all less than mortality rates observed in nature for the Hudson River (TI 1980a) and the Potomac River (Polgar 1977). Mortality rate estimates of 19.2 percent per day for finfold larvae (aged 13 to 23 days) in the Potomac River, and 14.2 percent per day (aged 13 to 22 days) for the Hudson River were reported. Obviously, these natural mortality rate estimates include predation which was eliminated in the long-term survival studies. Comparisons with the holding controls are useful indicators of stress associated with sampling and entrainment. Three of the four yolk-sac larvae and one-half of the post yolk-sac larvae experimental groups demonstrated higher survival than the holding control groups. This apparently indicates no long-term (14-day) entrainment associated effects.

In summary, the latent effects of entrainment for hatchery-reared striped bass varied by life stage, and sometimes by collection gear, but not by sampling station. Extended survival estimates for eggs were highly dependent upon the collection gear, with significantly higher survival observed with the plankton sampling flume. No significant differences in extended survival of yolk-sac larvae or post yolk-sac larvae were observed between intake and discharge samples collected with either the pumped or pumpless methods. Long-term (14-day) latent effects studies demonstrated that the effects of entrainment and sampling were detectable before 96 hours. Because no additional latent effects were apparent after 24 hours [similar observations made for wild striped bass collected in standard viability samples are discussed in (Section 6.3.3.1)] subsequent analyses used initial and 24-hour survival to assess the effects of entrainment on striped bass larvae; the percent hatch (96-hours) is used for eggs.

6.3.3.2.3 Evaluation of Mechanical and Thermal Effects During Direct Release

Mechanical stresses associated with pump mode (whether the circulator pumps were operated at full or throttled capacity) could not be evaluated during the 1979 direct release studies because two circulator pumps were always run at full capacity during the 14 sampling dates (Table L-1). It is assumed, however, that all decreases in survival that are not sampling-related will be mechanical when temperatures are less than 30 C. Mechanical effects during 1978 direct release studies were found to be low (EA 1979a).

Entrainment-related thermal effects were also difficult to evaluate during the 1979 direct release studies because the Bowline Point power plant generated electricity on only three of the fourteen sampling days (Table L-1). Even when power was generated (19, 20, and 22 June), the cooling water temperature rose only 2 to 3 C above ambient. The maximum temperature recorded at either of the discharge stations while electricity was being generated was 27.0 C, well below the lowest temperatures (30 C) at which any thermal effects are expected (EA 1979b) for striped bass post yolk-sac larvae. Although survival was consistently lower at the diffuser and discharge when there was a thermal discharge, compared to periods with no thermal load (Table 6-28), this lower survival was also noted at the intake with the pumped collection gear and, therefore, is more indicative of some other

TABLE 6-28 SURVIVAL OF STRIPED BASS POST YOLK-SAC LARVAE AT THE INTAKE, DISCHARGE STANDPIPE, AND DISCHARGE DIFFUSER OF THE BOWLINE POINT PLANT AS A FUNCTION OF TEMPERATURE EXPOSURE, 1979

Station	Temperature Range (C)	No. of Fish Collected	Initial Proportion Surviving	Latent (24-Hour) Proportion Surviving
Holding controls	20-26	438	1.000	0.808±0.019
Intake pump	23-24[a]	159	0.478±0.040	0.352±0.038
	20-22[b]	259	0.668±0.029	0.595±0.031
Intake pumpless	23-24[a]	119	0.899±0.028	0.807±0.036
	21-22[b]	270	0.800±0.024	0.670±0.029
Discharge standpipe--pump	26-27[a]	266	0.451±0.031	0.402±0.030
	20-25[b]	268	0.660±0.029	0.593±0.030
Discharge diffuser--pumpless	25-27[a]	57	0.421±0.065	0.386±0.064
	20-24[b]	65	0.631±0.060	0.554±0.062

(a) Collections on 19, 20, and 22 June.

(b) NT = No thermal addition, 31 May and 5, 6, 12, 13, and 25 June.

environmental or population differences among the batches of larvae than indicative of sublethal thermal stress associated with entrainment.

6.3.3.2.4 Relationship Between Survival and Total Length

Initial and 24-hour survival varied by length group, sampling station, and sampling gear (Table 6-29). Since differences between the pumped and pumpless collection systems were previously noted (Sections 6.3.3.2.1 and 6.3.3.2.2), analyses were performed on each collection method separately. Significant differences in initial survival (Table N-8) occurred among the four length groups examined for both the pumped and pumpless systems. Generally, the larger larvae exhibited a higher proprotion surviving (Figure 6-37). The exception to this trend occurred at the two discharge stations where survival decreased for the second length group (6 to 8.9 mm). Although station differences in survival were significant, any consistent patterns (Figure 6-37) between intake and discharge were generally masked by a strong three-way (total length x station x survival) interaction. The yolk-sac and early post yolk-sac larvae in the 6-8.9 mm length category (Table 6-29) appear slightly more susceptible to entrainment-related mortality than the 5 mm larvae. This pattern may be a result of increased sensitivity of larvae to stress during the transition from yolk-sac to post yolk-sac larvae.

Twenty-four hour survival showed nearly identical trends as the initial survival with significant differences among the four length groups observed with both the pumped and pumpless collection methods (Table N-9). Latent survival was extremely low (less than 10 percent, Table 6-29) for intake samples in the 3-5.9 mm length group and then it increased dramatically for larger larvae (Figure 6-38). Extended survival for collections at the discharge was fairly good (Table 6-29) for the smallest length group but declined for the 6-8.9 mm length group and then increased for the last two length groups. These station and size inconsistencies cause the three-way interactions to be highly significant ($\alpha = 0.001$) with both the pumped and pumpless collection method.

Yolk-sac larvae tested were either 5 or 6 mm in total length (Table 6-30). Early post yolk-sac larvae ranged from about 5 to 8 mm in total length while later post yolk-sac ranged up to 15 mm total length. Since differences in initial (Section 6.3.3.2.1) and extended (Section 6.3.3.2.2) survival were noted among life stages, it is not surprising that differences in survival were also observed among length groups.

6.3.3.2.5 Entrainment Survival During Direct Release

Entrainment survival was estimated by comparing survival at the intake pumped table to the discharge pumped table (standpipe) and the intake reardraw plankton flume to the diffuser pumpless plume. Initial and 96-hour entrainment survival estimates for striped bass eggs were lower at the discharge pumped station than the diffuser pumpless station (Table 6-31). Higher initial survival estimates of hatchery-reared striped bass eggs (6.3.3.2.1) were observed in collections with the pumpless collection systems.

Entrainment survival (S_e) of hatchery-reared striped bass yolk-sac larvae was 100 percent at both the discharge and diffuser stations, and at initial

TABLE 6-29 INITIAL AND 24-HOUR SURVIVAL BY LENGTH GROUP OF HATCHERY-REARED STRIPED BASS DURING DIRECT RELEASE STUDIES AT THE BOWLINE POINT PLANT, 1979

Station	Length (mm)	No. of Fish Measured	Initial Survival(a)	S_e (%) (Initial)(b)	No. of Fish Alive at 24 Hr	24-Hr Survival (P_s)	S_e (%) (24 Hr.)
Holding controls	3.0-5.9	76	1.000		44	0.759±0.057	
	6.0-8.9	203	1.000		144	0.709±0.032	
	9.0-11.9	119	1.000		104	0.874±0.030	
	12.0-14.9	15	1.000		14	0.933±0.065	
Intake--pump	3.0-5.9	118	0.297±0.042		8	0.068±0.023	
	6.0-8.9	165	0.467±0.039		63	0.382±0.038	
	9.0-11.9	170	0.500±0.038		64	0.376±0.037	
	12.0-14.9	19	0.632±0.111		9	0.474±0.115	
Intake--pumpless	3.0-5.9	96	0.156±0.037		6	0.063±0.025	
	6.0-8.9	166	0.578±0.038		63	0.380±0.038	
	9.0-11.9	108	0.887±0.030		87	0.806±0.038	
	12.0-14.9	5	1.000		5	1.000	
Discharge--pump	3.0-5.9	23	0.435±0.103	100.0	8	0.348±0.099	100.0
	6.0-8.9	108	0.361±0.046	77.3±12.4	24	0.222±0.040	58.1±11.9
	9.0-11.9	197	0.619±0.035	100.0	102	0.518±0.036	100.0
	12.0-14.9	17	0.588±0.119	93.0±24.9	10	0.588±0.119	100.0
Diffuser--pumpless	3.0-5.9	9	0.556±0.166	100.0	4	0.444±0.166	100.0
	6.0-8.9	55	0.182±0.052	31.5±9.2	5	0.091±0.039	23.9±10.5
	9.0-11.9	62	0.484±0.063	54.4±7.4	27	0.435±0.063	54.0±8.2
	12.0-14.9	4	0.500±0.250	50.0±25.0	2	0.500±0.250	50.0±25.0

(a) Initial proportion surviving = (no. live + no. stunned)/(no. live + no. stunned + no. dead).

(b) (Entrainment survival) = 100 x (proportion surviving entrainment + sampling)/proportion surviving sampling.

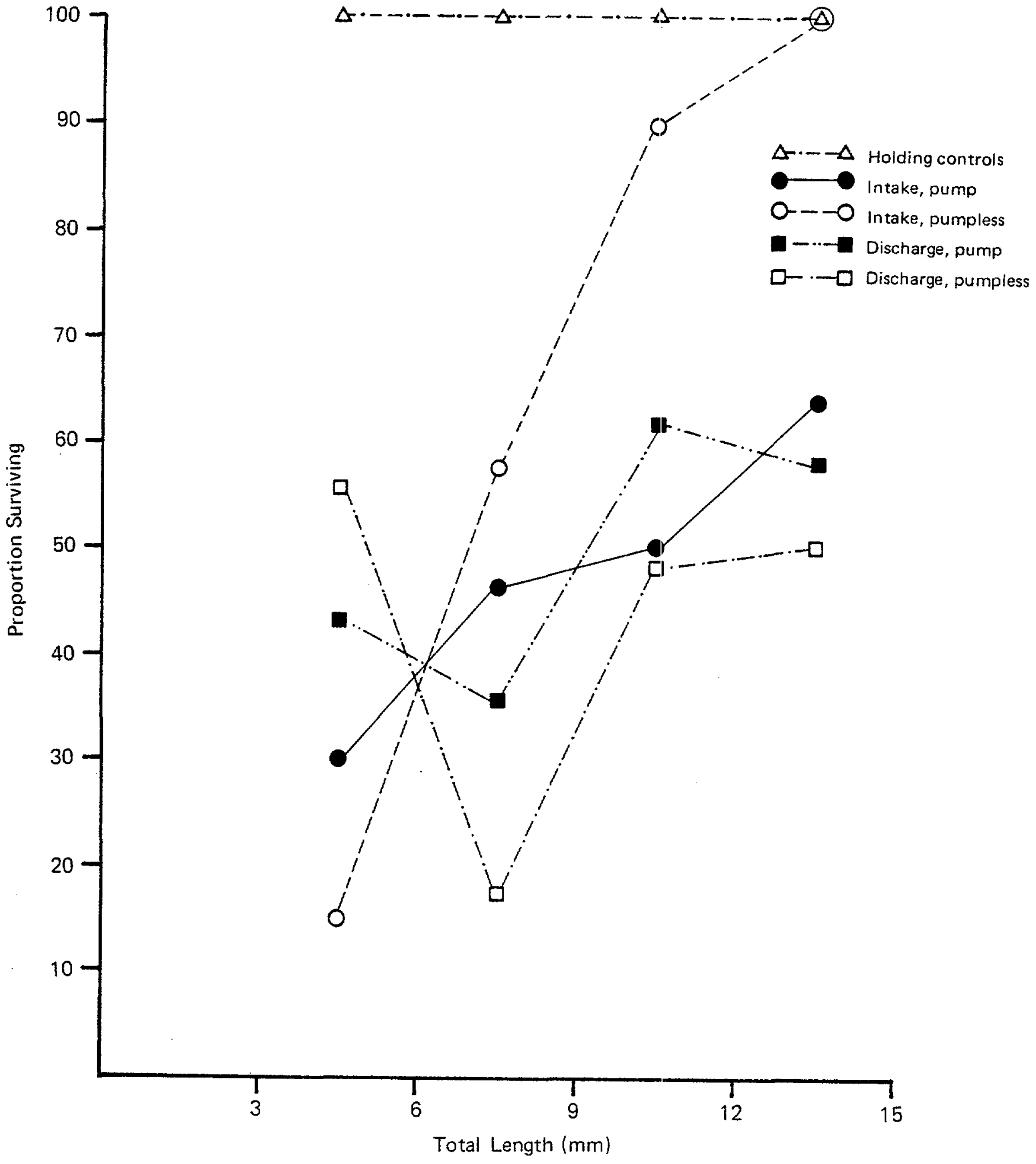


Figure 6-37. Initial survival by length group (mm) of hatchery-reared striped bass used in direct release studies at the Bowline Point plant, 1979.

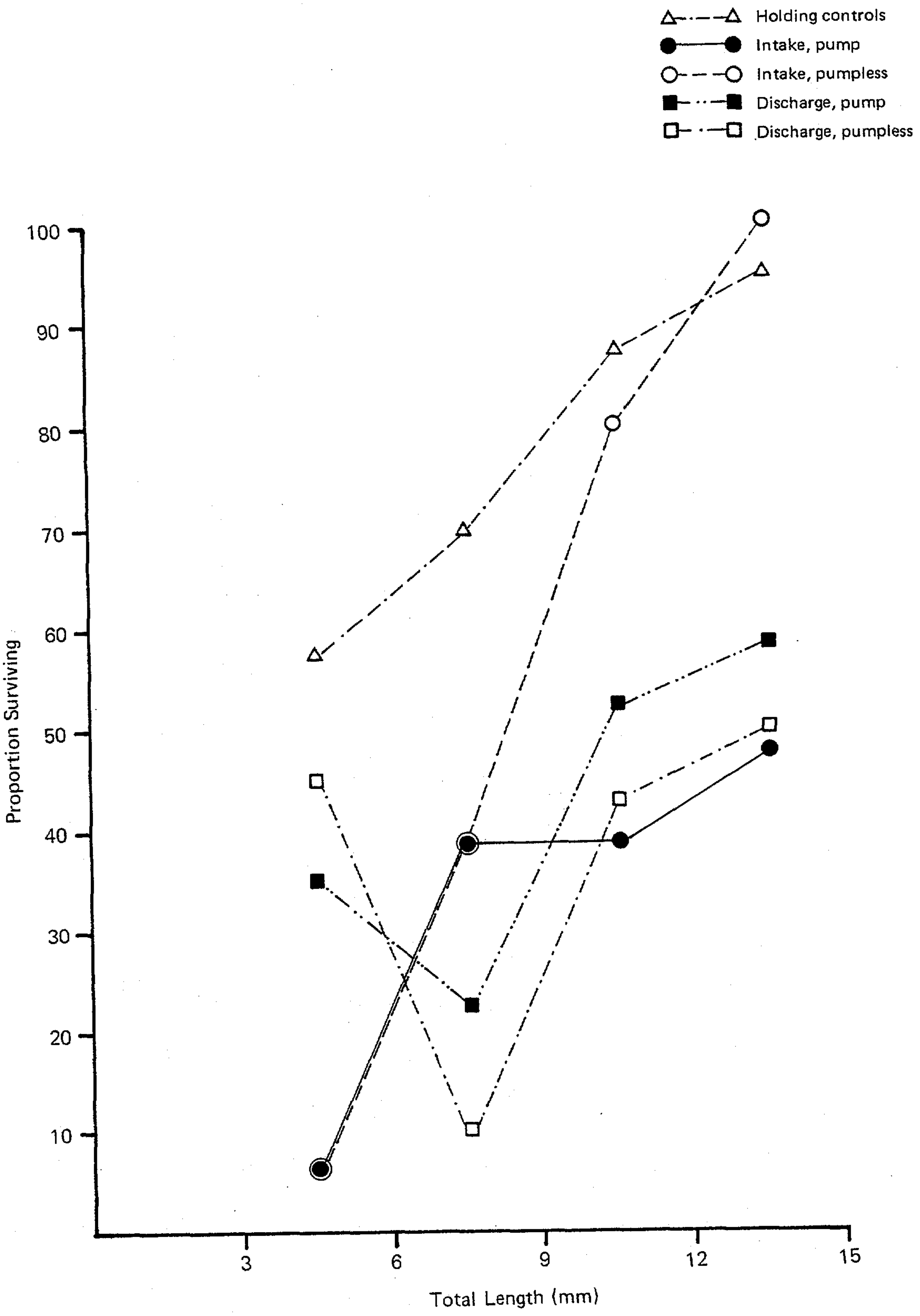


Figure 6-38. Extended (24 hour) survival by length group (mm) of hatchery-reared striped bass used in direct release studies at the Bowline Point plant, 1979.

TABLE 6-30 LENGTH FREQUENCY OF SUBSAMPLED HATCHERY-REARED STRIPED BASS LARVAE USED IN DIRECT RELEASE STUDIES AT THE BOWLINE POINT PLANT, 1979

Total Length (mm)	Date												Total	Percent
	Yolk-Sac Larvae			Early Post Yolk-Sac Larvae										
	24 MAY	25 MAY	29 MAY	31 MAY	5 JUN	6 JUN	12 JUN	13 JUN	19 JUN	20 JUN	22 JUN	25 JUN		
5	34	35	33	8									100	16.7
6	16	25	17	40	26	1							125	20.8
7				2	23	17	1						43	7.2
8					1	32	8	7					48	8.0
9							23	27	39	31	20		140	23.3
10							18	15	11	18	4	1	67	11.2
11								1		1	25	3	30	5.0
12											1	17	18	3.0
13												17	17	2.8
14												7	7	1.2
15												5	5	0.8

TABLE 6-31 ENTRAINMENT SURVIVAL OF HATCHERY-REARED STRIPED BASS AT THE BOWLINE POINT PLANT, DURING OPERATION WITH TWO PUMPS FULL, 1979

Life Stage	Temperature (C)	Number Collected				S_e (%)			
		Pump		Pumpless		Discharge		Diffuser	
		Intake	Discharge	Intake	Diffuser	Initial	24-Hour	Initial	24-Hour
Eggs	18-21	146	44	159	27	46.5±10.0	34.5±10.3*	81.9±8.6	89.3±9.0*
Yolk-sac larvae	18-20	193	100	212	45	100	100	100	100
Adjusted for dead			97		44	100		100	
Post-yolk larvae	19-27	418	534	389	122	93.3±5.3	99.2±6.5	64.2±5.6	66.7±6.7
Adjusted for nos. dead			491		109	100	100	71.7	71.2

(a) S_e (entrainment survival) = 100 x (Proportion Surviving Entrainment + Sampling)/Proportion Surviving Sampling.

*Percent hatch estimated for eggs at 96-hours.

and 24-hour observations. Striped bass post yolk-sac larvae entrainment survival (S_e) estimates were over 93 percent for collections at the pumped discharge station and approximately 65 percent for diffuser pumpless collections. Collections at the discharge standpipe exhibited entrainment survival estimates of 100 percent when adjustments were made for the number of dead organisms originally released at the intake (Table 6-31).

Entrainment survival estimates for larvae in the 3-5.9 mm length category (generally yolk-sac larvae) were 100 percent (Figure 6-39). Post yolk-sac larvae entrainment survival estimates generally increased with increasing size of the larvae. Entrainment survival estimates for post yolk-sac organisms collected at the discharge standpipe were consistently higher across all length groups than estimates for organisms collected at the discharge diffuser (Figure 6-39). While egg entrainment survival was higher at the diffuser (probably as a result of decreased sampling stress with the pumpless method of collection), entrainment survival of post yolk-sac larvae (which exhibited no collection gear effect, Table N-7) was lower at the diffuser. It appears, therefore, that some additional stress between the discharge standpipe and the diffuser may further reduce larval survival.

6.3.3.2.6 Sampling System Effects During Direct Release

Comparison of gear control survival with the corresponding experimental sample suggests that sampling stress is minimal (Table L-1). Approximately twenty-five organisms were released in the gear to evaluate sampling stress. No gear control experiments were conducted with eggs and yolk-sac larvae evaluated on only one day (Table L-1). Sampling stress on post yolk-sac larvae was evaluated on all collection dates. Lower survival observed for gear control organisms at the diffuser than at the pumpless intake may be the result of transport of the control organisms to and from the diffuser station (one-half mile by boat). Survival at the diffuser may also be lower in general because of rough water conditions at the offshore diffuser. Lower flow rates at the discharge (700-800 liter/min.) than at the intake (850-900 liter/min.) may have contributed to higher extended survival at the discharge. Studies conducted in 1978 (Appendix K, EA 1979a) indicate that survival decreased in the 10-foot larval table as flow was increased. Although flow rates and RPM were adjusted at each station to produce comparable samples, changes in tide height often caused a change in flow at the discharge. Generally higher extended survival observed for the discharge experimental and control samples, when compared with the corresponding intake survival, may have occurred because of occasional rough water in Bowline Pond.

6.3.3.2.7 Recovery Efficiency During Direct Release

Recovery efficiency based on direct release experiments in 1979 ranged from 20 to 246 percent of the expected number of hatchery-reared organisms (Table 6-32). Recovery of eggs ranged from 20 to 52 percent, yolk-sac larvae from 44 to 71 percent, and post yolk-sac larvae from 91 to 246 percent. The overall percent recovery was: 35 percent for eggs, 55 percent for yolk-sac larvae, and 162 percent for post yolk-sac larvae (Table 6-33).

Recovery of hatchery-reared striped bass at the discharge indicated that over 95 percent of the eggs and larvae released at the intake pass the discharge

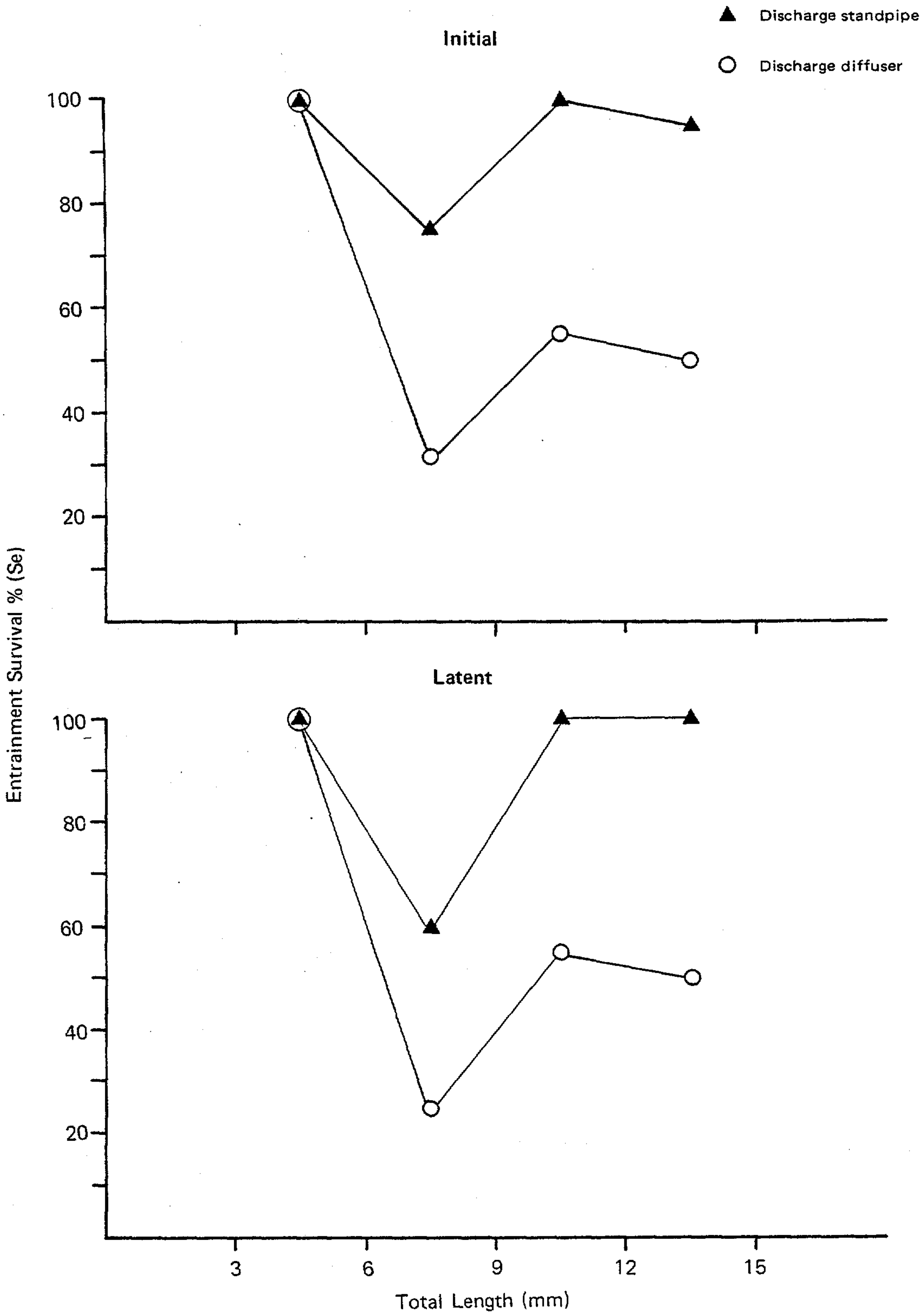


Figure 6-39. Entrainment survival (Se) of hatchery-reared striped bass larvae by length group collected at the Bowline Point plant, 1979.

TABLE 6-32 EXPECTED AND ACTUAL NUMBER OF HATCHERY-REARED STRIPED BASS RECOVERED FROM THE DISCHARGE STANDPIPE AND THE DISCHARGE DIFFUSER AT THE BOWLINE POINT PLANT FOLLOWING RELEASE OF AN ESTIMATED POPULATION AT THE INTAKE DURING MAY AND JUNE, 1979

Release Date	Station	Gear	Life Stage/Age	Volume Sampled (m^3)	Pump Operation	Estimated Number Released	Expected Number Recovered	Actual Number Recovered[(a)]	Percent of Expected Number
22 MAY	Discharge standpipe	Larval table	Eggs/3 days since ovulation	9.6	2 full	75,000	40	9	
	Discharge diffuser	Larval table		10.2			43	8	
							Σ = 83	Σ = 17	20
24 MAY	Discharge standpipe	Larval table	Eggs/2 days since ovulation	11.5	2 full	75,000	48	11	
	Discharge standpipe	Manual nets		22.2			46	21	
	Discharge diffuser	Larval table		10.0			42	19	
							Σ = 136	Σ = 51	38
24 MAY	Discharge standpipe	Larval table	Yolk-sac larvae/5 days	11.5	2 full	92,213±15,450	59±10	31	
	Discharge standpipe	Manual nets		22.2			57±10	27	
	Discharge diffuser	Larval table		10.0			51±9	16	
							Σ = 167	Σ = 74	44
25 MAY	Discharge standpipe	Larval table	Yolk-sac larvae/3 days	12.4	2 full	75,886±15,614	52±11	44	
	Discharge standpipe	Manual nets		23.1			52±10	30	
	Discharge diffuser	Larval table		11.0			47±10	23	
							Σ = 151	Σ = 107	71
29 MAY	Discharge standpipe	Larval table	Yolk-sac larvae/4 days	10.4	2 full	48,339±7,445	28±4	26	
	Discharge standpipe	Manual nets		20.6			30±5	19	
	Discharge diffuser	Larval table		12.2			33±5	10	
							Σ = 91	Σ = 45	49
31 MAY	Discharge standpipe	Larval table	Post yolk-sac larvae/9 days	11.3	2 full	77,299±12,520	49±8	44	
	Discharge standpipe	Manual nets		21.9			47±8	71	
	Discharge diffuser	Larval table		10.6			46±7	27	
							Σ = 142	Σ = 142	100
5 JUN	Discharge standpipe	Larval table	Post yolk-sac larvae/ 14 and 7 days	14.0	2 full	59,100±6,666	Σ = 46±5	Σ = 42	91
6 JUN	Discharge standpipe	Larval table	Post yolk-sac larvae/ 16 days	13.0	2 full	46,561±3,790	Σ = 34±3	Σ = 62	182
12 JUN	Discharge standpipe	Larval table	Post yolk-sac larvae/ 21 days	10.6	2 full	51,058±7,182	30±4	37	
	Discharge standpipe	Manual nets		14.1			25±5	51	
	Discharge diffuser	Larval table		10.1			29±4	16	
							Σ = 84	Σ = 104	124

(a) No. recovered corrected for wild larvae collected in sample as predicted by pre- and post-release samples.

TABLE 6-32 (CONT.)

Release Date	Station	Gear	Life Stage/Age	Volume Sampled (m^3)	Pump Operation	Estimated Number Released	Expected Number Recovered	Actual Number Recovered[a]	Percent of Expected Number
13 JUN	Discharge standpipe	Larval table	Post yolk-sac larvae/ 22 days	10.5	2 full	24,896±7,561	15±4	44	
	Discharge standpipe	Manual nets		13.6			16±5	43	
	Discharge diffuser	Larval table		10.2			14±4	17	
							Σ = 45	Σ = 104	221
19 JUN	Discharge standpipe	Larval table	Post yolk-sac larvae/ 21 days	12.5	2 full	45,444±13,283	32±9	73	
	Discharge standpipe	Manual nets		12.2			29±8	71	
	Discharge diffuser	Larval table		10.0			25±7	9	
							Σ = 86	Σ = 153	178
20 JUN	Discharge standpipe	Larval table	Post yolk-sac larvae/ 22 days	11.8	2 full	76,129±26,264	50±17	149	
	Discharge standpipe	Manual nets		11.2			45±15	152	
	Discharge diffuser	Larval table		9.2			39±13	29	
							Σ = 134	Σ = 330	246
22 JUN	Discharge standpipe	Larval table	Post yolk-sac larvae/ 23 days	11.5	2 full	45,668±5,852	29±4	44	
	Discharge standpipe	Manual nets		10.7			26±3	45	
	Discharge diffuser	Larval table		11.2			29±4	19	
							Σ = 84	Σ = 108	129
25 JUN	Discharge standpipe	Larval table	Post yolk-sac larvae/ 31 days	10.9	2 full	19,179±5,638	12±3	30	
	Discharge standpipe	Manual nets		10.8			11±3	35	
	Discharge diffuser	Larval table		11.2			12±4	6	
							Σ = 35	Σ = 71	203

TABLE 6-33 EXPECTED AND ACTUAL NUMBER OF HATCHERY-REARED STRIPED BASS RECOVERD FROM THE DISCHARGE STANDPIPE (BOTH LARVAL TABLE AND MANUAL NETS) AND DISCHARGE DIFFUSER AT THE BOWLINE POINT PLANT FOLLOWING RELEASE OF AN ESTIMATED POPULATION AT THE INTAKE, 1979

	No. Expected	No. Observed	Percent of Expected No.
Eggs			
Standpipe larval table	140	47	34
Standpipe manual nets	46	21	46
Diffuser larval table	85	27	32
Total	271	95	35
Yolk-sac larvae			
Standpipe larval table	139	101	73
Standpipe manual nets	139	76	55
Diffuser larval table	131	49	37
Total	409	226	55
Post yolk-sac larvae			
Standpipe larval table	297	525	177
Standpipe manual nets	199	468	235
Diffuser larval table	194	123	63
Total	690	1,116	162

within the standard 15-minute sample interval (Figure 6-40). Eleven tests were conducted to evaluate recovery using the manual net at the discharge standpipe (Appendix Figures R-1 through R-5). Nearly one-half (49.9 percent) of the total number were recovered from 8 to 10 minutes after release (Figure 6-40). This period of peak recovery occurred from 2 to 4 minutes after the estimated transit time, based on plant specifications (Figures R-1 through R-5) and may be a result of larvae resisting the flow at the intake and not entering the cooling system immediately following release. In addition the release of all larvae from the release tank generally took approximately 2 to 3 minutes.

The percent of the expected number of striped bass eggs recovered (Table 6-33) did not vary greatly. A slightly higher percent of eggs (46 versus 34) were collected with the manual net versus the larval tables at the standpipe. The diffuser larval table collections (Table 6-33) always yielded the lowest percent of expected numbers collected. This lower value for the diffuser may occur if water discharge was non-uniformly distributed among the eight discharge ports. That is, if the discharge volume decreases along the length of the diffuser the volume and number of larvae exiting the number 6 diffuser port may be lower than expected. The percent of expected numbers collected increased with the age (life stage) of the organisms (Table 6-33).

The extremely large variation in recovery efficiency estimates makes statistical analyses and interpretation of these data difficult. That is, real differences in recovery efficiency, which may exist between life stages or gear, are masked by variations inherent in the sampling methods and procedures. Thus, any mathematical attempt to relate recovery efficiency to some other variable would probably explain only a small amount of the total variation.

The high variability in recovery efficiency may be caused by the interaction between nonuniform distribution of organisms and the volume of water sampled. If organisms are distributed uniformly within the effluent water each sample will collect organisms in direct proportion to the volume strained. However, if organisms are randomly distributed, variation will occur in sample densities. If samples are small (i.e., the expected number of organisms to be captured is small based on the true mean density and the volume sampled), variation in density estimates will be high. If organisms are patchily distributed, however, as is often the case for ichthyoplankton, then small samples, which have small expected numbers of recaptures, will be even more variable and frequently result in an underestimate of the true mean density.

Although a great deal of mixing occurs after water passes through the condensers, it is unlikely that it would be sufficient to randomize the distributions of organisms that were extremely patchy upon entering the intake. Mixing, however, is probably sufficient to eliminate stratification, i.e., systematic nonrandomness, thus providing unbiased sampling at any point within the discharge pipe if samples are large enough to effectively average densities over dense and sparse patches. Consequently, large samples, i.e., those which have high expected numbers of recoveries, will have relatively less variation than small samples which have small expected values.

Another potential source of variation which has not been examined is the dispersion dynamics of larvae released at the intake. Although larvae were

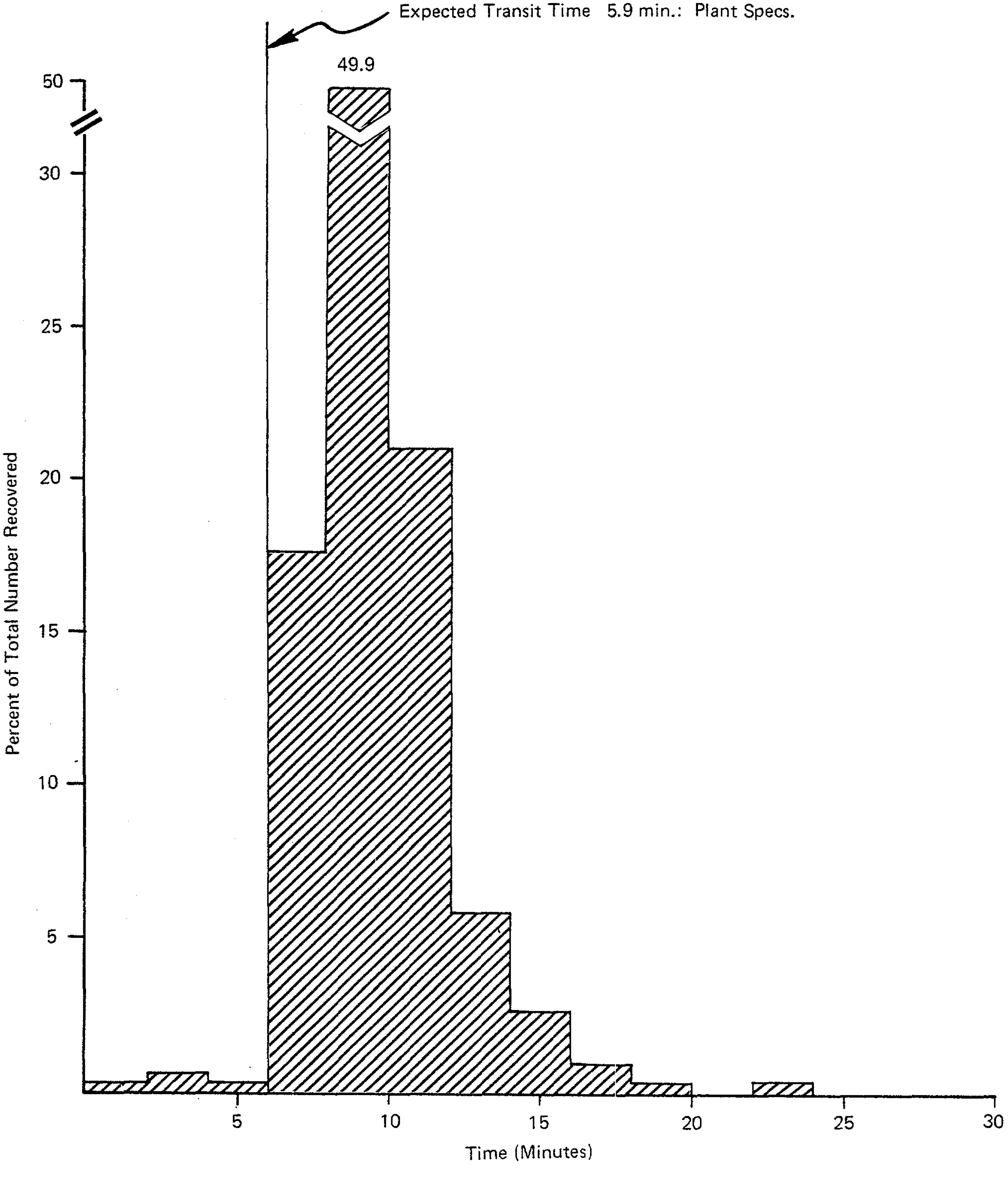


Figure 6-40. Recovery of hatchery-reared striped bass (eggs and larvae combined) collected by 2-minute intervals at the discharge standpipe (with manual nets) of the Bowline Point plant, 1979.

released near the traveling screen, it is possible that they may remain within the intake structure for an extended period or escap from the intake prior to entrainment. Thus the expected numbers would be overestimated if based on the total population released.

To obtain precise estimates of recovery efficiency, inherent variability of the sampling methods and procedures must be reduced as much as possible. Large numbers of hatchery-reared organisms should be used so that expected numbers of recoveries are as large as possible. As a further step toward high expected recoveries, only high volume sampling gear should be used. Of course, the expected number recovered is based upon the estimated number released. The wide standard errors associated with the population estimates indicate the difficulty in obtaining accurate and/or precise population estimates. Difficulty was encountered in obtaining a homogeneous mixture of organisms in the holding tank; however, the primary objective was to evaluate survival rather than estimate number released.

6.3.3.2.8 Comparison of Hatchery and Wild Striped Bass

Initial and extended (24-hour) survival of hatchery-reared and wild striped bass differed by life stage, sampling station, and sampling gear (Table 6-34). No wild striped bass eggs were collected during 1979. There were 43 wild yolk-sac larvae collected, however, the uneven distribution among intake (13) and discharge (30) stations preclude statistical comparisons with hatchery-reared released striped bass. Two hundred and thirty-two wild striped bass post yolk-sac larvae were collected, which was sufficient to allow statistical comparisons with 1,463 hatchery-reared post yolk-sac larvae.

The overall tests of independence for post yolk-sac larvae among station (intake pump, intake pumpless, discharge pump, and diffuser pumpless), origin (hatchery-reared versus wild), and survival were highly significant, with 10 degrees of freedom (Table N-10). Both initial and extended survival were dependent upon the origin of the organisms collected. Wild striped bass post yolk-sac larvae survived at the intake pumped larval table better than hatchery reared post yolk-sac larvae for both initial and latent (24-hour) observations, but for the other three collection stations at both observations, the survival was better for hatchery-reared organisms (Table 6-34).

Extended (24-hour) survival did not differ significantly among the four stations, however, initial survival did differ. The station by survival G value (107.62) for initial survival was partitioned into the two intake and two discharge stations and then compared by intake versus discharge. Differences in survival were found between the pumped and pumpless collections at the intake, but not at the discharge. The intake and discharge survival comparison was significant (Table N-10) with the discharge stations always having lower initial survival than the intake collections (Table 6-34). Although wild post yolk-sac larvae collected at the discharge stations exhibited lower survival than they did at the intake stations, this trend was reversed for hatchery-reared striped bass. This crossover in survival between stations results in no significant extended survival differences, but contributed greatly to the significant three-factor (station x origin x survival) interaction. No significant three-interaction (Table N-10) was noted for initial survival.

TABLE 6-34 COMPARISON OF WILD AND HATCHERY-REARED STRIPED BASS COLLECTED AT THE BOWLINE POINT PLANT DURING 1979

		Wild			Hatchery-Reared		
			Proportion Surviving			Proportion Surviving	
Life Stage	Station	Number Collected	Initial	24 Hour(a)	Number Collected	Initial	24 Hour
Eggs	Intake-pump	0	--	--	146	0.733	0.822
	Intake-pumpless	0	--	--	159	0.950	0.960
	Discharge-pump	0	--	--	44	0.341	0.600
	Diffuser-pumpless	0	--	--	27	0.778	1.000
Yolk-sac larvae	Intake-pump	6	0.833	1.000	193	0.316	0.557
	Intake-pumpless	7	1.000	0.857	212	0.179	0.737
	Discharge-pump	19	0.632	0.833	100	0.320	0.750
	Diffuser-pumpless	11	0.636	0.571	45	0.289	0.769
Post yolk-sac larvae	Intake-pump	31	0.710	0.864	418	0.596	0.843
	Intake-pumpless	46	0.630	0.793	389	0.830	0.858
	Discharge-pump	104	0.413	0.605	534	0.556	0.896
	Diffuser-pumpless	51	0.353	0.333	122	0.533	0.892

(a) Normalized.

Survival of hatchery-reared striped bass generally increased with the increase in length of the larvae. This pattern was not generally observed for wild larvae, however, over two-thirds (175 of 254) of the wild larvae fell within one length group (6.0-8.9 mm). With limited sample sizes outside of this one length group and extended over four sampling stations, comparisons of hatchery-reared and wild organisms would be invalid.

6.3.3.2.9 Summary of Direct Release Studies

Initial survival of hatchery-reared striped bass varied by life stage, sampling station, and sampling gear. Yolk-sac larvae exhibited the lowest survival followed by post yolk-sac larvae and eggs. Significantly ($\alpha = 0.05$) higher survival occurred at the intake than discharge station and pumpless versus pumped collection methods for eggs. No significant difference in survival was noted between the intake and discharge stations but the pumped larval table demonstrated higher survival of yolk-sac larvae. Post yolk-sac larvae survival was higher at the intake than discharge station.

Extended survival of hatchery-reared striped bass varied by life stage and sometimes by collection gear, but not by sampling station. Extended survival estimates for eggs were highly dependent upon the collection gear, with significantly higher survival observed with the pumpless plankton flume. No significant differences in 24-hour survival of yolk-sac larvae or post yolk-sac larvae were observed between intake and discharge samples collected with either the pumped or pumpless sampling gear. Long-term (14-day) latent effect studies demonstrated that any effects of entrainment and sampling would be detectable before 96 hours.

Mechanical stresses associated with pump mode (whether the circulator pumps were operated at full or throttled capacity) were unable to be evaluated during the 1979 direct release studies since two circulator pumps were always run at full capacity during the fourteen sampling dates. Entrainment-related thermal effects were also difficult to evaluate since the Bowline Point plant generated electricity on only three of the fourteen sampling dates. The maximum temperature recorded at either of the discharge stations while electricity was being generated was 27.0 C, well below the lowest temperature (30 C) where any thermal effects are manifest (EA 1979b) for striped bass post yolk-sac larvae. It is assumed, however, that all decreases in survival that are not sampling-related will be mechanical when temperatures are less than 30 C.

Significant differences ($\alpha = 0.05$) in initial and extended (24-hour) survival were detected among examined length groups that were collected with the pumped and pumpless collection gear. Generally, the larger the hatchery-reared striped bass larvae, the greater the proportion surviving.

Entrainment survival (S_e) of hatchery-reared striped bass yolk-sac larvae was 100 percent at both the discharge and diffuser station, initially and 24 hours following entrainment. Post yolk-sac larvae entrainment survival estimates generally increased with the size of the larvae. Entrainment survival estimates for post yolk-sac larvae collected at the discharge standpipe were consistently higher across all length groups than estimates for organisms collected at the discharge diffuser.

Recovery of marked hatchery-reared striped bass at the discharge indicated that over 95 percent of the eggs and larvae released at the intake pass the discharge within the standard 15-minute sample interval. Recovery of eggs ranged from 20 to 52 percent (mean of 35), yolk-sac larvae from 44 to 71 percent (mean of 55), and post yolk-sac larvae from 91 to 246 percent (mean of 162).

Both initial and 24-hour survival differed between hatchery-reared and wild striped bass post yolk-sac larvae. In general, hatchery-reared post yolk-sac larvae had slightly better survival than wild fish.

Unequal and unevenly distributed sample sizes among life stages, length groups, and sampling stations make statistical comparisons between hatchery-reared and wild striped bass difficult.

6.4 OVERVIEW OF ENTRAINMENT SURVIVAL AT THE BOWLINE POINT PLANT--1975 TO 1979

6.4.1 Introduction

In this section, yearly survival data collected with pumped larval tables at the Bowline Point plant from 1975 through 1979 are analyzed as a single data base to identify the most significant factors influencing the survival of entrained ichthyoplankton. The small sample sizes and apparent inconsistency among entrainment survival estimates (S_e) for individual years (Table 6-35) make it difficult to assess the sources of entrainment mortality, the predicted impact, and impact mitigation measures. By consolidating the five annual data bases, increased sample sizes are obtained and a stepwise evaluation of the factors influencing entrainment survival has been made. With this approach the variability has been partitioned using combinations of biological and plant operational factors which may be important for predictive impact assessment.

This analysis of entrainment survival followed four steps.

1. Annual data bases were examined to identify population and sampling differences which may have caused inter-year variation and thus precluded pooling of data across years.

2. Survival curves were examined for potential latent effects which may have reduced survival during the 96 hours following entrainment.

3. The effect of plant operational factors (e.g., pumping mode and discharge temperature) on survival were evaluated at the appropriate time interval to account for both initial and possible latent effects.

4. Entrainment survival (S_e) estimates were calculated using intake and discharge survival data partitioned among the primary population and plant operational characteristics that influenced survival.

6.4.2 Methods

In the past five years of study at the Bowline Point plant, length was found to be an important factor in entrainment survival of fishes, with higher survival nearly always being observed for the larger organisms. The annual

TABLE 6-35 INITIAL ENTRAINMENT SURVIVAL OF MECHANICAL ENTRAINMENT STRESS$^{(a)}$ AT THE BOWLINE POINT PLANT, 1975-1979

		1975			1976			1977			1978			1979		
Species	Life Stage	N_I	N_D	S_e (%)	N_I	N_D	S_e (%)	N_I	N_D	S_e (%)	N_I	N_D	S_e (%)	N_I	N_D	S_e (%)
Striped bass	Yolk-sac larvae	2	--	--	10	1	--	1	7	--	55	80	100	6	17	70$^{(c)}$
	Post yolk-sac larvae	136	105	91	118	146	77	228	358	97	591	379	100	31	101	60
	Juvenile	--	--	--	13	35	97	12	70	90	2	19	--	--	--	--
White perch	Yolk-sac larvae	1	--	--	--	--	--	--	--	--	21	10	--$^{(b)}$	7	13	8$^{(c)}$
	Post yolk-sac larvae	125	153	100	55	23	100	26	23	62	190	245	52	136	106	43
	Juvenile	--	--	--	7	6	--	1	4	--	3	1	--	--	--	--
Clupeids	Yolk-sac larvae	--	--	--	--	--	--	--	--	--	0	1	--	--	--	--
	Post yolk-sac larvae	24	16	100	46	58	80	37	18	51	53	215	100	45	52	58
	Juvenile	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Atlantic tomcod	Yolk-sac larvae	--	--	--	280	143	100	372	499	84	3	9	--	NS		
	Post yolk-sac larvae	--	--	--	54	17	54	8	1	--	49	54	--			
	Juvenile	--	--	--	--	--	--	--	--	--	8	0	--	NS		

(a) Observed survival is presented for organisms captured at discharge temperatures less than 20.0 C for Atlantic tomcod, 33.0 C for Morone juveniles, and 30.0 C for all other species/life stages.

(b) No yolk-sac white perch were collected alive at the discharge and only one alive at the intake; therefore no S_e was calculated.

(c) Survival estimate based on unadjusted discharge survival; S_e was not calculated (P_{sD}/P_{sI}) when less than 10 organisms were collected at either station.

Note:
N_I = number collected at intake
N_D = number collected at discharge
S_e(%) = entrainment survival
NS = no sampling

length distribution of the most abundant species were examined because differences in the rate of increase in spring river temperatures (discussed with regard to life stage abundance in entrainment abundance samples--Section 6.2.3.3) can influence larval growth rates. Additionally, differences in time and duration among the sampling seasons may influence the proportion of various length groups in the survival samples. A test of independence using contingency analysis was therefore used to assess the interactions between survival and year as might be affected by length distribution differences. The results of these analyses were used as a guideline for the consolidation of the annual data bases.

The effects of entrainment may be manifested as initial mortality or as behavioral, physiological, or morphological responses to stress which may or may not result in latent mortality subsequent to entrainment. It is therefore necessary to determine when estimates of survival will account for the full mortality-associated effects of entrainment. To differentiate the combined latent effects of collection, handling, and holding stresses from those related to entrainment, the intake and discharge survival curves for those organisms surviving initially are compared. Typically, the survival curves decline sharply during the first 12 hours following entrainment and then level off after 24 hours. The rate of decline between 24 and 96 hours was examined for the intake and discharge stations using contingency analyses to determine if the survival rates for the two stations were similar. Lack of a significant difference between these rates indicates that no latent entrainment mortality occurs after 24 hours. A determination of whether differences between the stations which may occur by 24 hours (the break point of the survival curves) are significant will then indicate if a latent entrainment effect is manifest during the first 24 hours following entrainment. Where no significant differences are observed no latent effects were apparent; therefore, initial survival reflects the full mortality due to entrainment. If significant differences occur at or subsequent to 24 hours an observation period is selected which will account for latent effects in the entrainment survival estimate.

The two primary causes of entrainment mortality are thermal and mechanical stress. Controlled laboratory estimates of thermal mortality and field estimates of mechanical mortality can be combined in predictive models to estimate the overall effect of entrainment on survival of the most abundant ichthyoplankton taxa. In the following sections, two approaches have been used to estimate survival from mechanical stress for entrained striped bass and white perch. First, survival data were pooled within length groups based on statistical similarity, life history, and length-frequency information. Survival estimates were then made for length groups which approximate the life stages historically used for impact assessment at the Bowline Point plant. Although certain survival trends are obvious from the life stage approach, trends within these life stages and some natural variability among 1-mm length groups would not be observed with this approach. Since life stages tend to be a somewhat arbitrary categorization and length has been demonstrated to be a primary factor influencing survival, a second approach has been examined to estimate entrainment survival for the continuum of lengths within the sampled population. Because the number of organisms collected varies widely among 1-mm length intervals a certain amount of "noise" can be observed in the relationships among pump mode, length, and survival described above. Furthermore, where sample size for a life stage is very small (less than 10 organisms), estimates of entrainment survival have generally not been made because high variance estimates (variance calculations for binomial distributions, such as survival data, are primarily dependent on sample size) limit the interpretative value and biological significance of such estimates. To take advantage of all of the available data (including small samples), linear regression analysis (Dixon and Brown 1977) was used to fit a function to the survival by length data. The number of organisms collected at each length was used as a weighting variable to prevent small samples from disproportionately influencing the calculated relationship. The fitted function was used to predict survival for any length at the intake and discharge stations. These predicted values were used to estimate entrainment survival.

Laboratory studies indicate that for white perch and striped bass larvae the threshold at which mortality due to thermal exposure begins to occur in discharge samples is between 30 and 33 C (30-40 minutes exposure), while a rapid decrease in survival can be expected at temperatures in excess of 33 C (EA 1978b, 1979b). No thermal-related decrease in survival is expected below 30 C. Assuming that thermal and mechanical stresses act independently, any entrainment-related mortality observed at discharge temperatures less than 30 C is representative of the mechanical effects of entrainment. Where sufficient data are available, survival was compared for organisms collected at temperatures below 30 C, between 30 and 33 C, and above 33 C. However, since temperature exposure durations cannot be controlled during collection, as in laboratory studies, these data were not used to make estimates of thermal mortality which would occur in passage through the power plant.

6.4.3 Results and Discussion

Striped bass and white perch were generally most abundant at those lengths (6 to 8 mm) typical of the transition between yolk-sac and post yolk-sac larvae (Figures 6-41, 6-42, and Appendix O). However, the abundance of larvae in excess of 9 mm varied considerably between years. For example, few striped bass larger than 9 mm were collected in 1975 and 1979, while 10-mm and larger fish formed a substantial portion of the 1976, 1977, and 1978 sampling effort (Figure 6-41). A similar pattern can be observed for white perch with a sharp contrast in the length-frequency distributions of 1978-1979 versus 1975-1977 (Figure 6-42). Atlantic tomcod were primarily collected over a very narrow range of lengths from 6 to 8 mm (Figure 6-43).

Since survival typically increases with length, differences in the relative abundance of length groups within a life stage (e.g., early versus late post yolk-sac larvae) can result in considerable differences among the annual survival estimates for each life stage. The relationship between length and survival for each year is apparent from a graphic examination of the data (Figures 6-44 and 6-45) for white perch collected at the intake and discharge and striped bass collected at the discharge. Contingency analysis demonstrated significant ($p < 0.001$) two-factor interactions for all combinations of year, length, and survival of white perch (Appendix Table R-1). The conclusion to be drawn from these graphical and contingency analyses is that, while significant differences in white perch survival occur among years (year x survival interaction) most of this annual variability is explained by differences in length distribution (significant length x year interaction) in conjunction

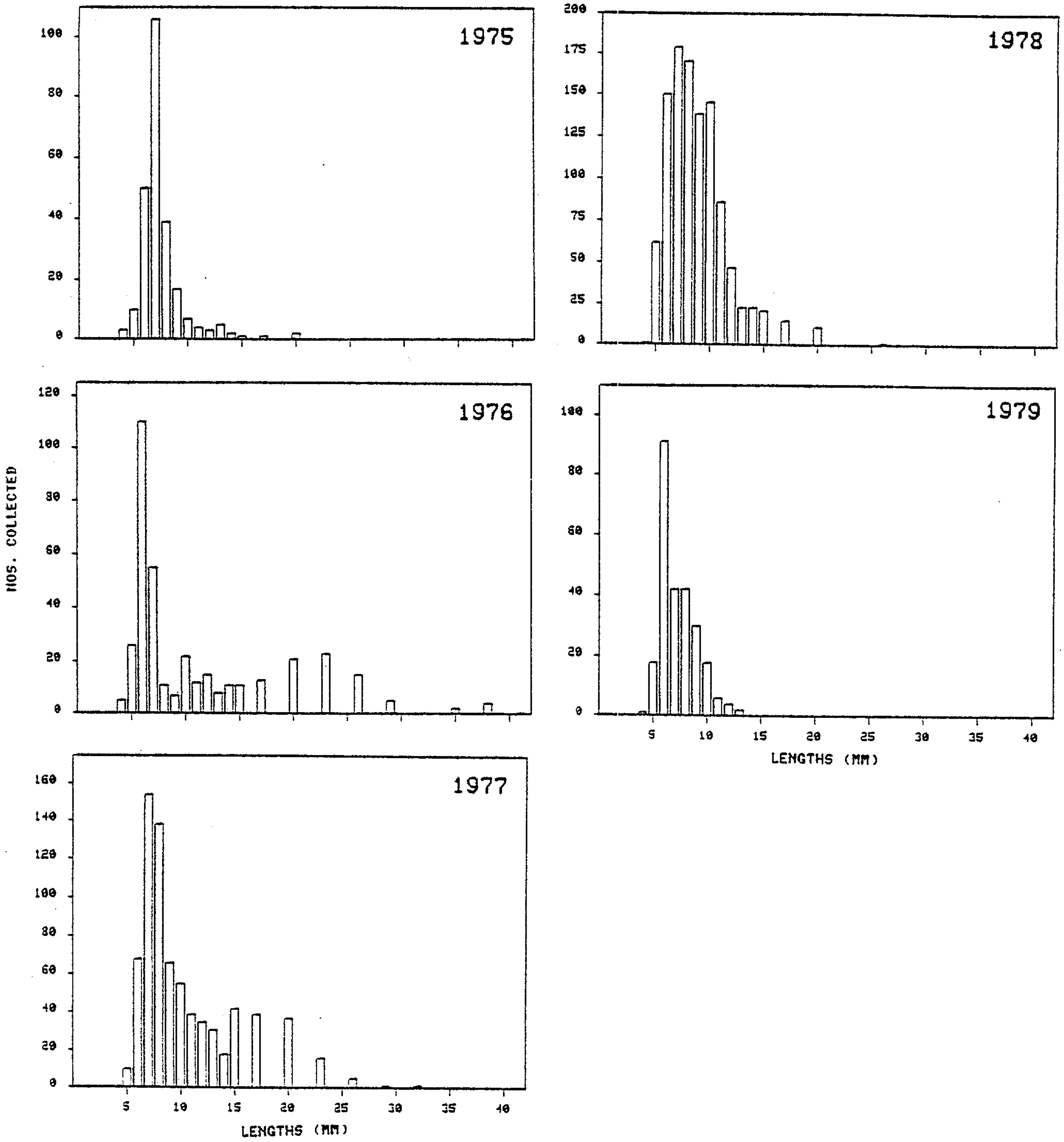


Figure 6-41. Annual length frequency distributions of striped bass collected during entrainment survival studies at the Bowline Point plant, 1975–1979.

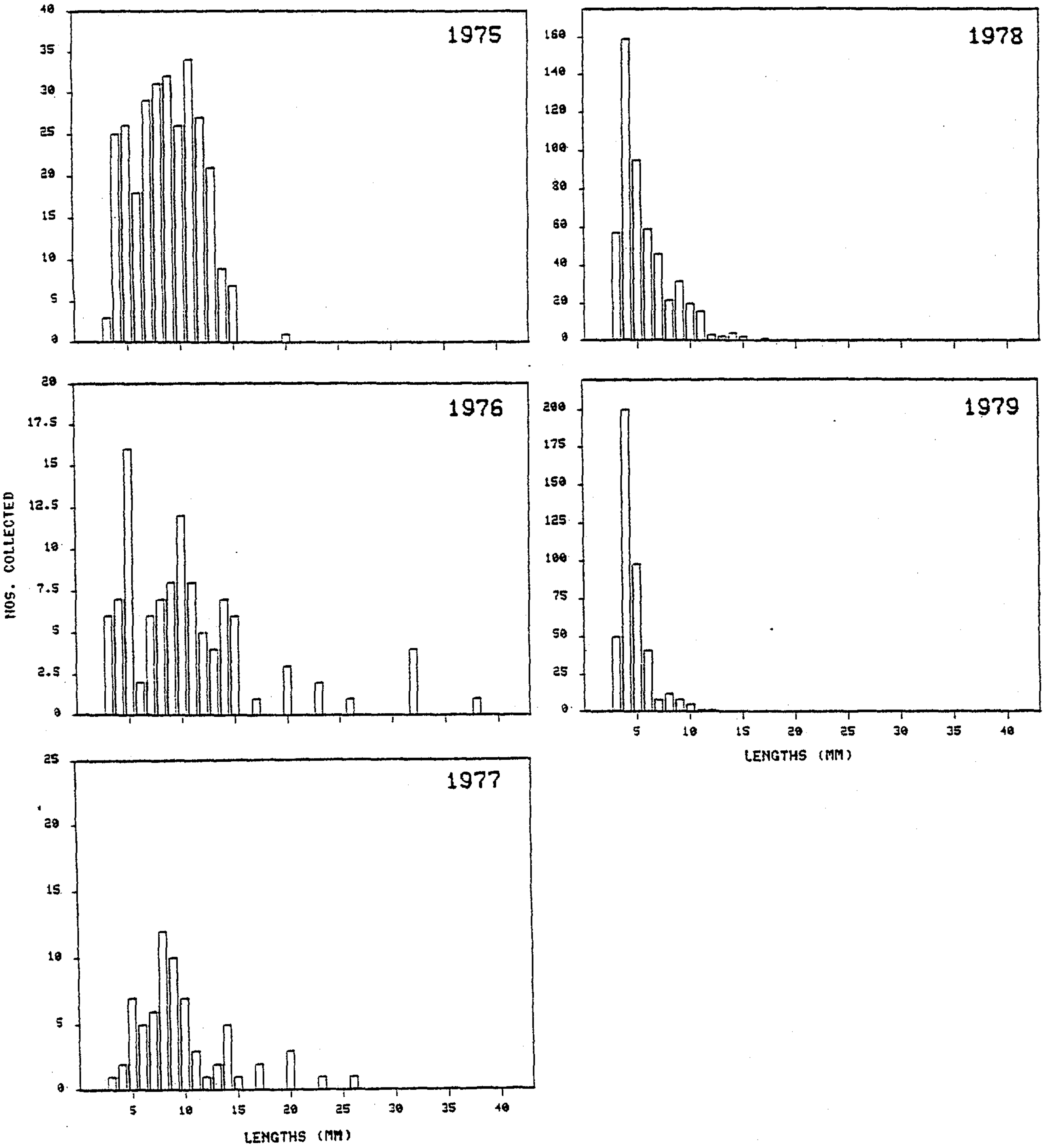


Figure 6-42. Annual length frequency distributions of white perch collected during entrainment survival studies at the Bowline Point plant, 1975–1979.

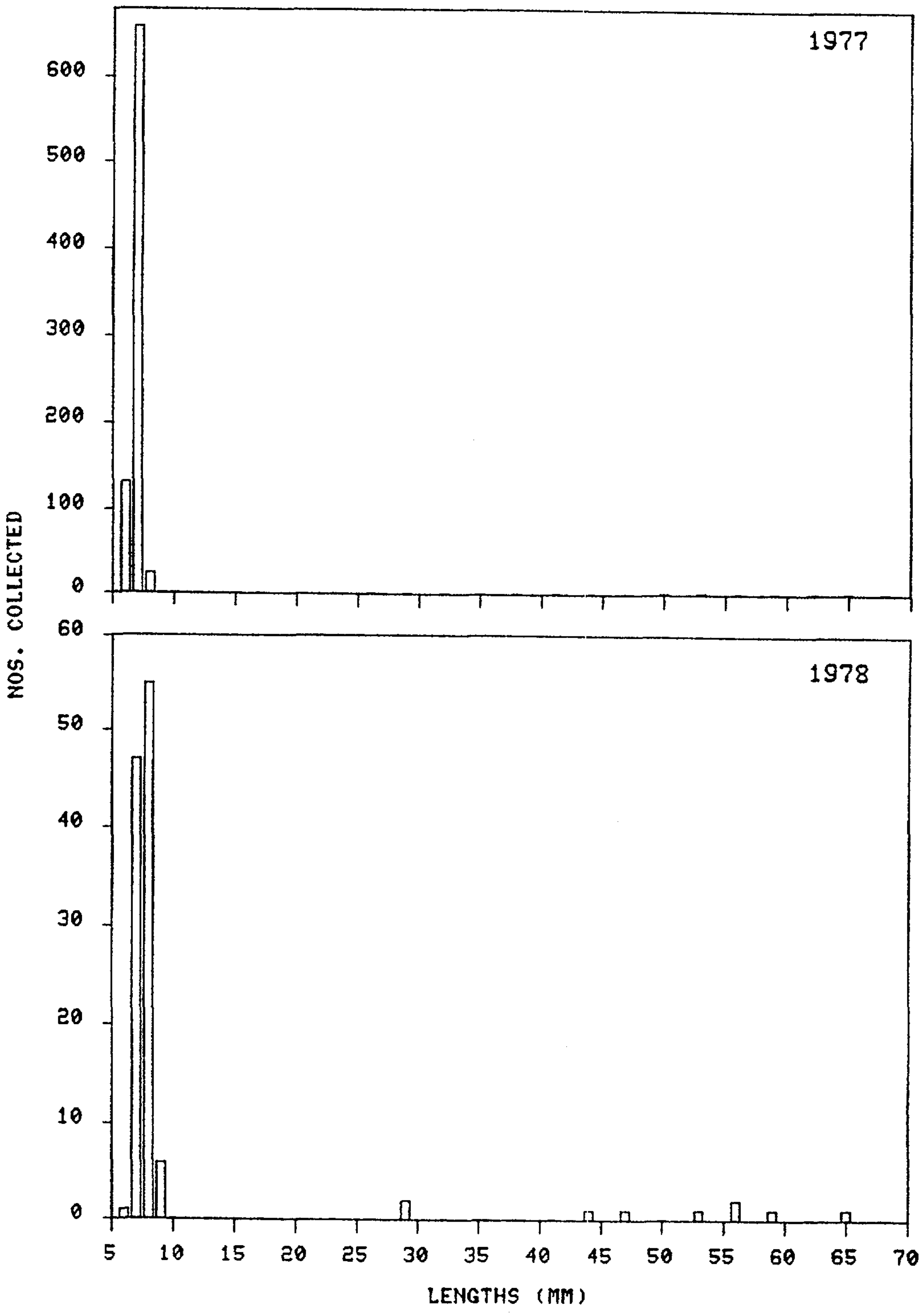
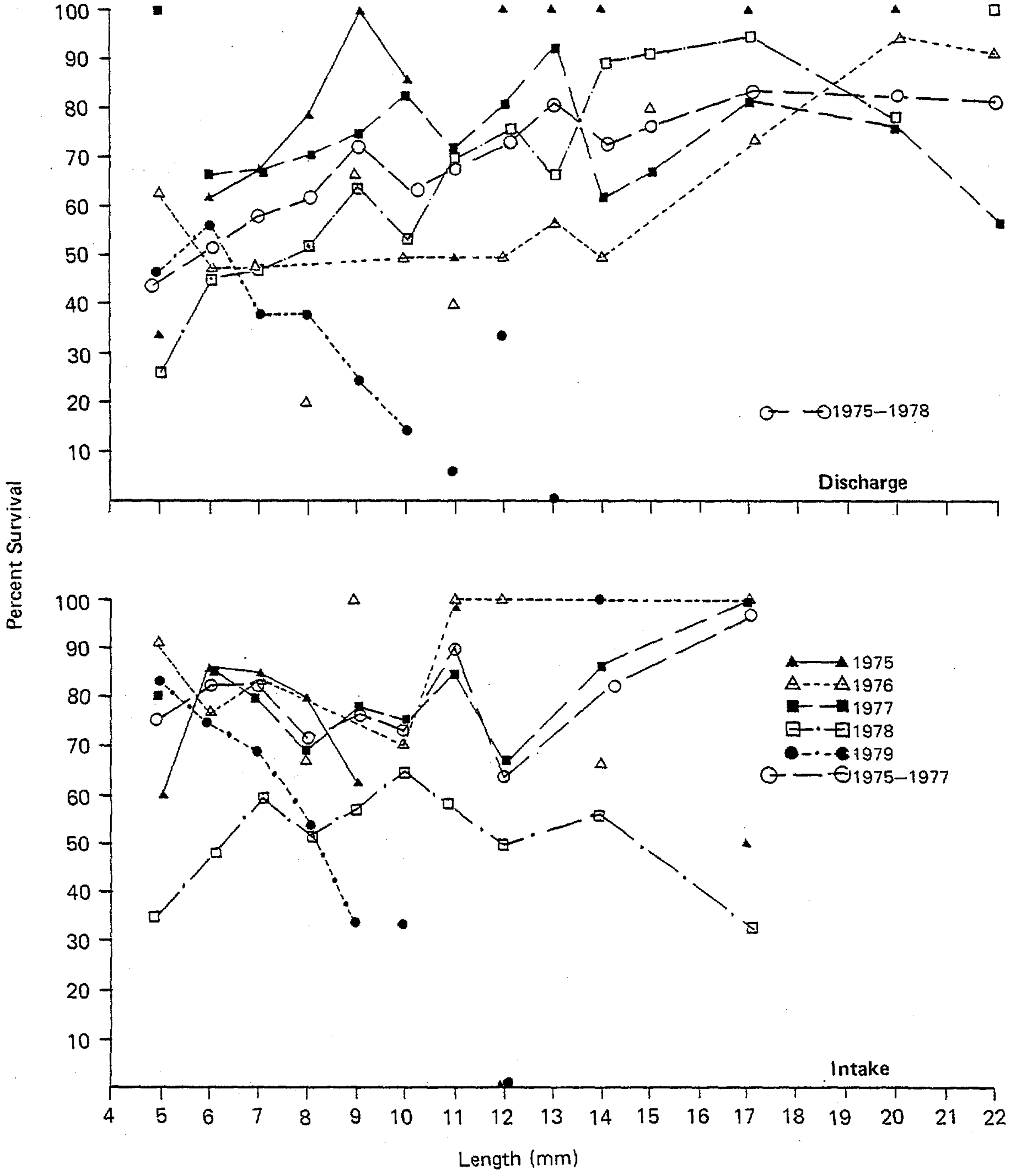
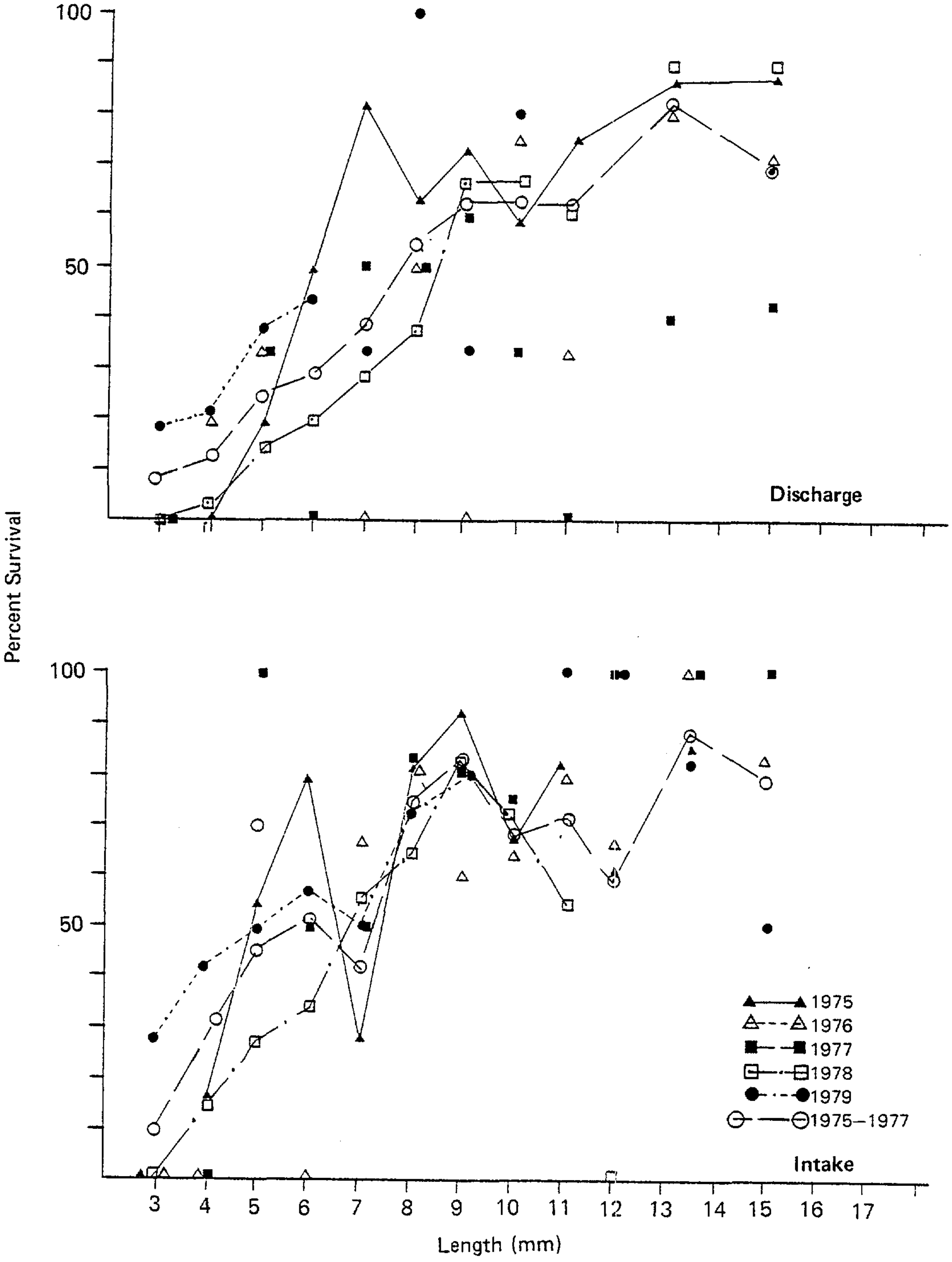


Figure 6-43. Annual length frequency distributions for Atlantic tomcod collected during entrainment survival studies at the Bowline Point plant, 1977–1978.



Note — Data points not connected represent less than 7 fish.

Figure 6-44. Summary of survival by length for striped bass during entrainment studies conducted at the Bowline Point plant, 1975–1979.



Note—data points not connected represent less than 7 fish.

Figure 6-45. Summary of survival by length for white perch collected during entrainment studies at the Bowline Point plant, 1975–1979.

with the relationship between survival and length (significant length x survival interaction).

A similar relationship was observed for striped bass collected at the discharge; however, survival of small organisms was higher than for white perch and the increase in survival with length was not as rapid as observed for white perch (Figure 6-44). This is reflected in the lower G value observed for striped bass (Appendix Table P-2) relative to white perch. The atypical decrease in survival with length observed for 1979 (Figure 6-44) is an artifact of the long-term holding studies conducted in 1979 (see Sections 6.3.2.1.3, 6.3.3.1.3, and 6.3.3.1.5). Live fish which were held beyond 96 hours were fed and would consequently be expected to exhibit a higher rate of growth than fish held through 96 hours. Higher growth rates and the greater elapsed time between entrainment and measurement would result in lengths which do not reflect those at the time of entrainment. Therefore, no fish held beyond the standard 96 hours were measured. Consequently, these unmeasured live fish are excluded from initial survival estimates made by length with the result that survival is underestimated. Since larger organisms have a higher survival rate it is likely that more large organisms are excluded; therefore, the apparent decrease in survival becomes more pronounced as size increases. White perch survival was not similarly affected in 1979 because few white perch were held past 96 hours (Sections 6.3.3.1.2 and 6.3.3.1.5).

Survival of striped bass at the intake exhibited no significant length effect (Table P-2). Furthermore, for the years 1975 through 1977, no significant annual differences in survival were observed although the length distribution was significantly different (Table P-2). Intake survival during 1979 showed the same atypical decline with length observed at the discharge as a result of the extended holding and measurement procedures and was therefore excluded from analyses. In addition, during 1978 survival was consistently lower (by 10 to 60 percent) over all lengths than in previous years. This appears to be a result of an interaction between a high intake suction head and the collection pump used; 1978 was the only year during which a 4-in. (10 cm) Homelite trash pump was used to collect samples at the intake structure walkway (4-5 m above water level). The Homelite pump was used at water level in 1977 and 1979 and a Midland Midwhirl 4-in. pump was used on the walkway in 1975 and 1976. The potential difference in collection effect between these two pumps, operated with a large suction head, is also indicated by survival studies conducted at the Roseton and Danskammer Generating Stations (EA 1980a, 1980b) during 1978. Although all other methodology was similar, a Homelite pump was used at the Danskammer Point plant intake where survival was 27 percent and a Midland pump was used at the Roseton plant where survival was 79 percent for post yolk-sac larvae. This differential was particularly apparent for larvae less than 12 mm.

Based on the length x year x survival analyses, subsequent analyses will be made with the data from all years pooled within 1-mm length intervals. That is, since statistical and graphical analyses indicate that survival increased with length it appears that differences in length distribution among years account for much of the observed differences in overall annual survival. The years used in the subsequent analyses were as follows:

Species	Station	Years
Striped bass	Intake	1975-1977
	Discharge	1975-1978
White perch	Intake and discharge	1975-1979
Atlantic tomcod	Intake and discharge	1976-1978

It is important to recognize from these results that length, not life stage, is the primary factor related to age and sensitivity of larvae to both collection and entrainment stresses. This is particularly noteworthy since the peak abundance of entrained organisms occurs at length intervals typical of transition between yolk-sac and post yolk-sac larvae (Appendix O) for both striped bass and white perch. Furthermore, the primary characteristics used in laboratory separation of these life stages is somewhat arbitrary, based on the presence or absence of food in the gut, irrelevant of whether an organism still possesses a yolk-sac. Since the historical approach to entrainment impact analysis has focused on life stages, length groups have been regrouped for selected analyses to approximate life stages based on the life stage length histograms (Appendix O) and further statistical analysis in order to calculate S_e.

Ninety-eight percent of the Atlantic tomcod collected during 1977 and 1978 were 6 to 8 mm and no consistent trend in survival was observed with length. Therefore, all lengths have been pooled for subsequent analyses. Pooling across length and year would further permit inclusion of 1976 tomcod survival data. No lengths were recorded in 1976, however, over 85 percent of the Atlantic tomcod were classified as yolk-sac larvae indicating that most of these larvae were within a length range similar to 1977 and 1978.

The survival curves for striped bass, white perch, and Atlantic tomcod decline sharply during the first 12 hours to approximately 75, 50, and 80 percent survival, respectively (Figure 6-46 and Appendix Tables Q-1 to Q-3). After 12 hours the curves for both intake and discharge stations level out and become approxiimately parallel to the horizontal axis. No significant difference ($p>0.05$) was detected between the mortality rates at the intake and discharge (station x survival independence) from 24 to 96 hours for any species length group except for 5-mm striped bass (Table P-3). These data indicate that the intake and discharge curves are parallel; that is, the rate of mortality is not greater at the discharge than the intake as might be indicated if the curve diverged as converged. Although the curves for both white perch and striped bass are parallel, a continued slight decline in survival was observed for length groups (observation interval x survival interaction) at the yolk-sac to post yolk-sac transition (Table P-3). This rate of decline (5-10 percent), however, is not inconsistent with the natural rate of mortality (14.2-16.4 percent for striped bass during 1977 and 1978) observed for these length intervals in the Hudson River (TI 1980a).

At 24 hours, normalized survival was not significantly different between intake and discharge for striped bass (Table P-4). On the other hand, the differences between stations existing at 24 hours (Figure 6-46) were significant for white perch (Table P-4). Survival of Atlantic tomcod collected at the discharge was slightly higher than at the intake. Therefore, no statistically significant latent entrainment effects occur throughout the 96 hours following entrainment of striped bass and Atlantic tomcod. White perch,

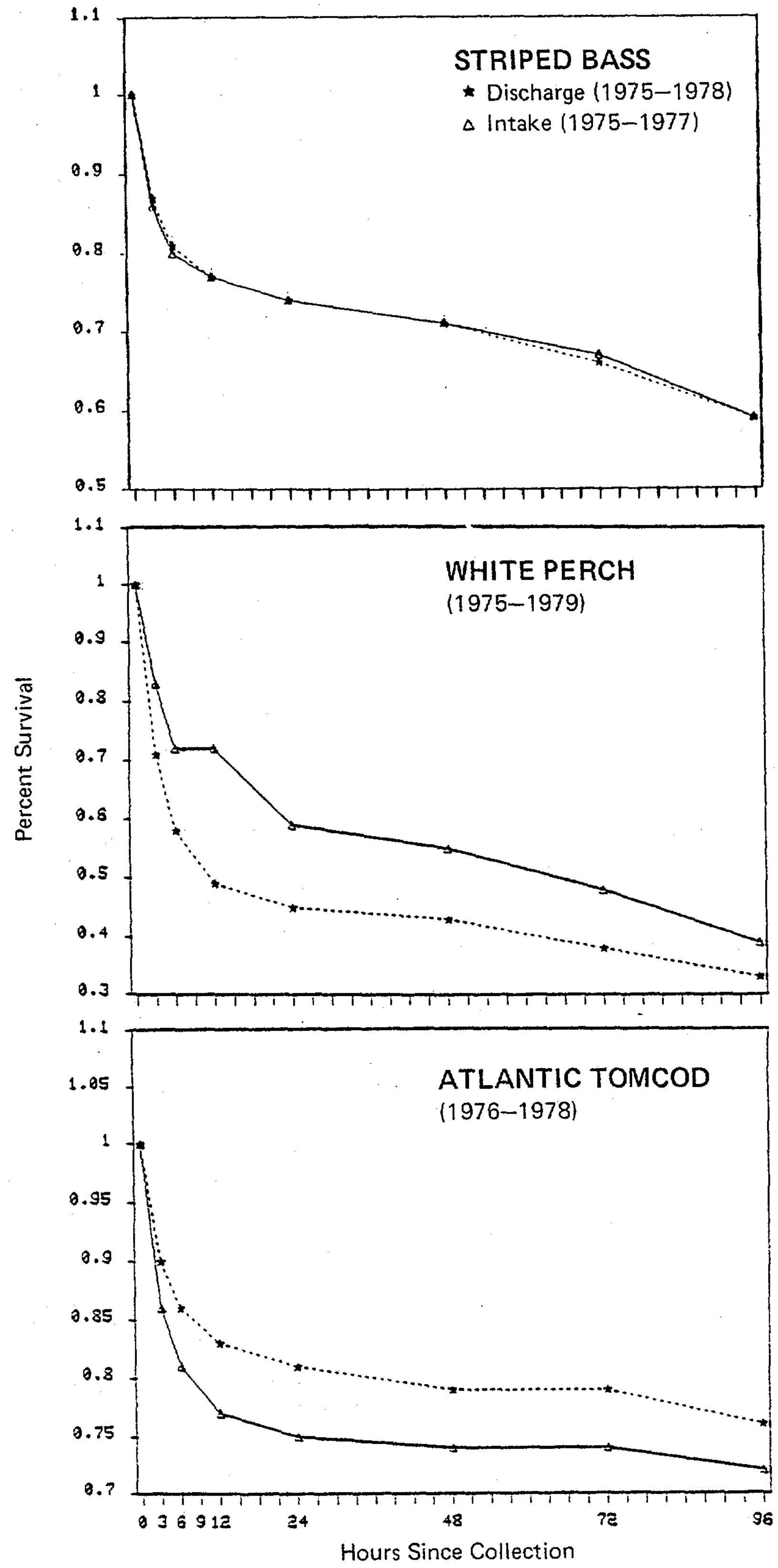


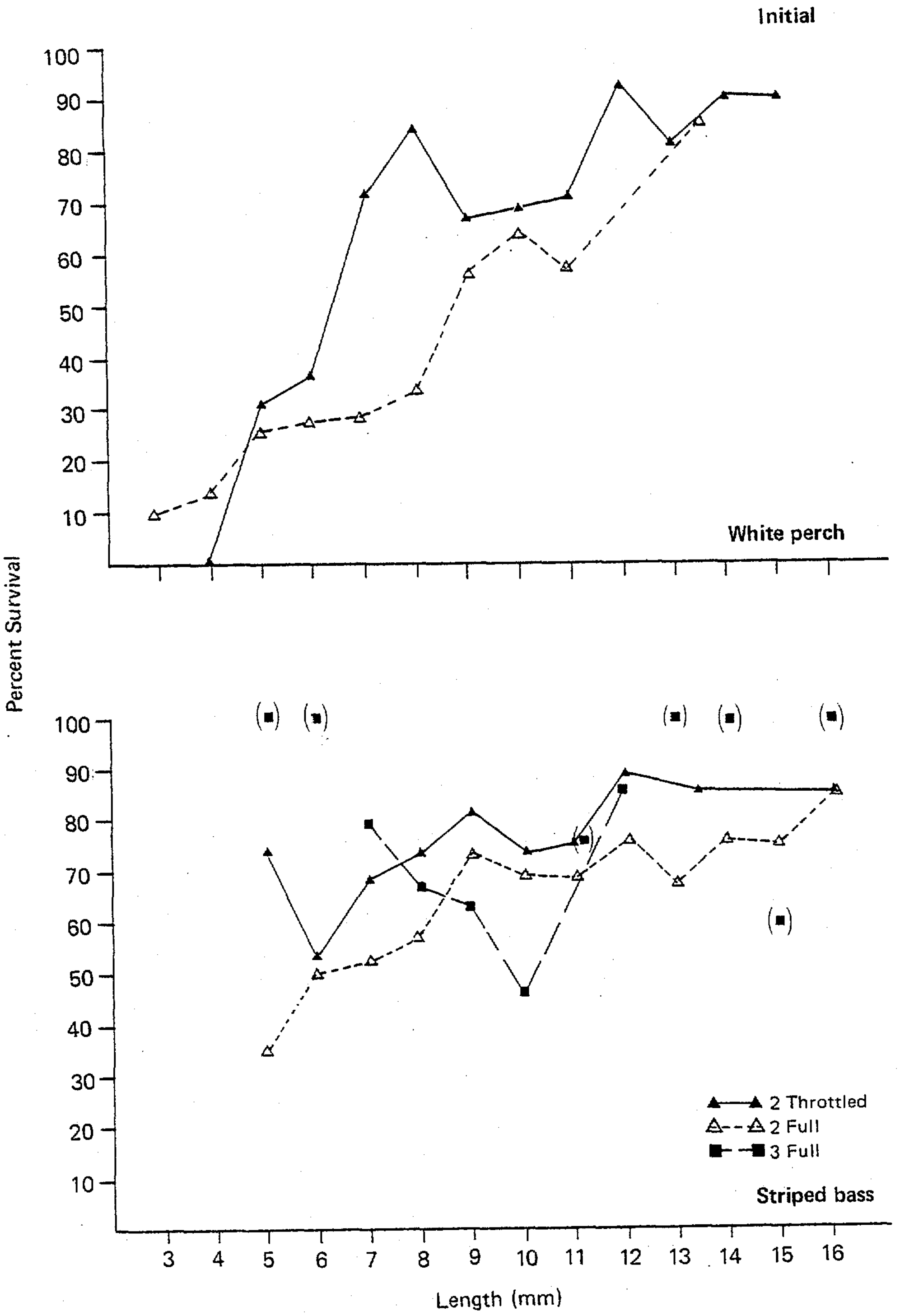
Figure 6-46. Survival curves for striped bass, white perch, and Atlantic tomcod collected alive at the intake and discharge of the Bowline Point plant.

however, exhibit a latent entrainment effect which is manifest during the first 24 hours following entrainment and estimates of entrainment survival based on the number alive at 24 hours and the total number collected will account for both the initial and latent sources of mortality.

Analysis of intake samples indicates that sampling mortality is similar under the three circulating pump operating modes characteristic of the Bowline Point plant (Table P-5). Contingency analysis demonstrated a non-homogeneous length distribution across pump modes for both white perch and striped bass, reflecting the greater relative abundance of larger fish as flow was increased later in the entrainment season. However, since no significant interactions were observed between survival and pump mode, sampling mortality can be estimated for each length group by pooling data collected at all pump modes. Since sampling mortality is similar for all pump modes, it has been assumed that differences in discharge survival which might be observed for the three pumping modes at less than 30 C are a result of associated differences in the magnitude of various mechanical stresses experienced during entrainment.

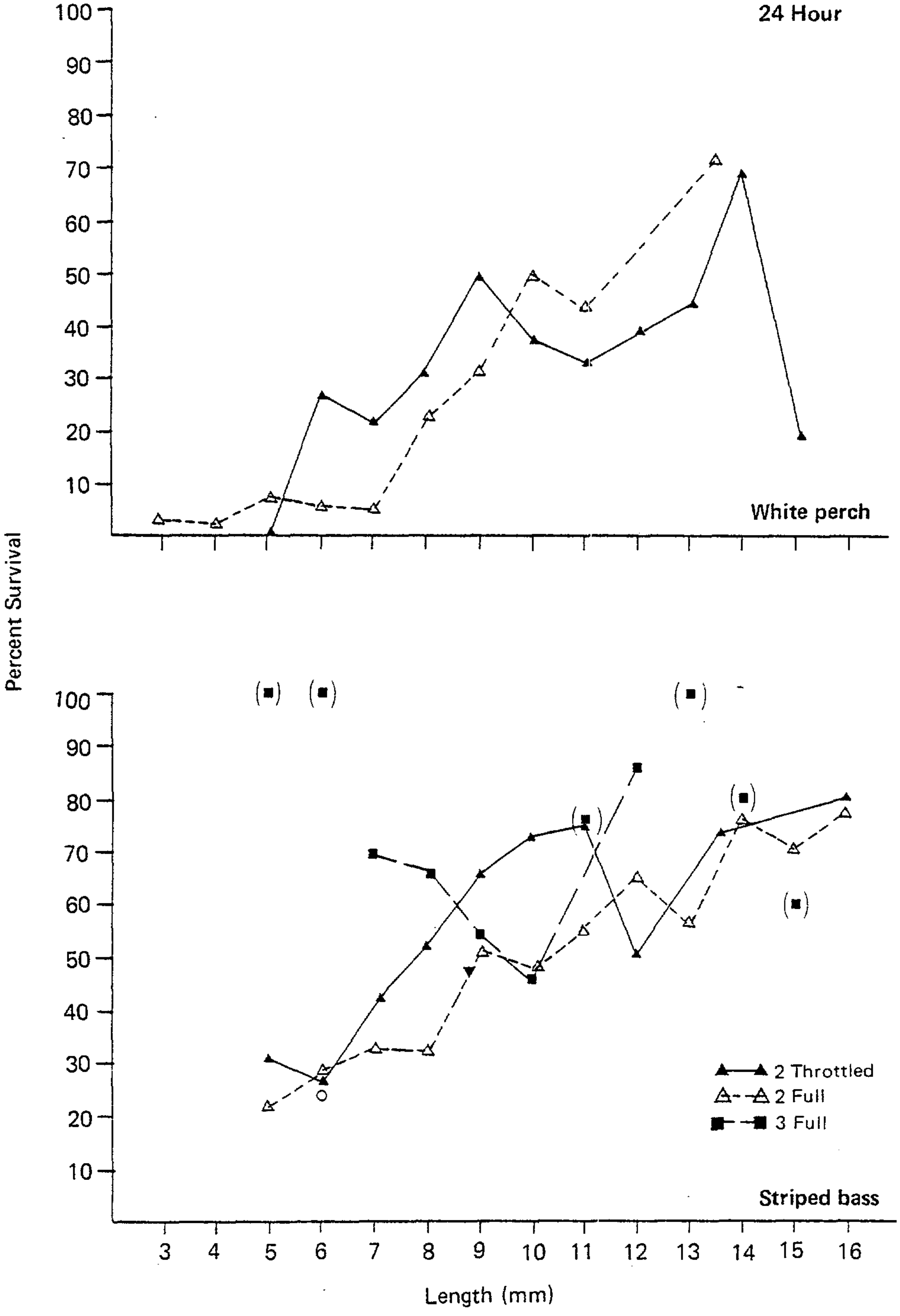
Similar to the intake, the uneven distribution of lengths among the three pump modes accounts for much of the difference in survival for both striped bass and white perch collected at the discharge during different pump modes. The interactions between length and pump mode, and length and survival were highly significant for both species (Tables P-6 and P-7). The relationship between pump mode and survival, however, was not as clear. While initial survival during two-pump throttled operation is higher than during two-full operation, the difference (particularly for striped bass and white perch greater than 10 mm, Figure 6-47) is obscured by 24 hours. In fact, the partial and marginal associations in a three-way contingency analysis give inconsistent results for white perch (Table P-6) which indicate that the interaction between pump mode and survival is of questionable or secondary importance (Brown 1976). Furthermore, partitioning the G-statistic for striped bass shows that across all lengths initial survival during two-pump full operation differs significantly from the other two modes, while at 24 hours survival for three-pump full operation differs from the combined two-pump operation mode (Table P-7).

While some of the differences in survival among pump modes were found to be statistically significant the relationship among pump mode, mechanical stress, and survival is not clear. Some of the primary mechanical stresses which may result in mortality of entrained fish are rapid decreases in pressure (NYU 1975), shear forces (Morgan et al. 1973, 1976), and abrasion. The pressure decreases are largest for two-throttled and smallest for two-full operation (ORU 1977). However, survival is generally higher for the throttled mode which is the opposite of the result expected if pressure is a major factor. Cada et al. (1980) also found that, contrary to their expected hypothesis (that reduced pumping efficiency, i.e., throttled mode, would result in reduced survival), no clear relationship existed between the effects of pump passage at different pumping rates and survival. Cada et al. did, however, find that mortality as a result of condenser passage increased with flow, a fact not demonstrated at the Bowline Point plant. Shear forces are generally more severe at higher flows (velocities). However, survival of all lengths of striped bass at Bowline Point was greatest for three-pump full operation (highest flow). Based on the analyses of survival data from



( ) Denotes less than 7 organisms.

Figure 6-47. Survival of striped bass and white perch collected at the Bowline Point plant discharge by length and pump operating mode.

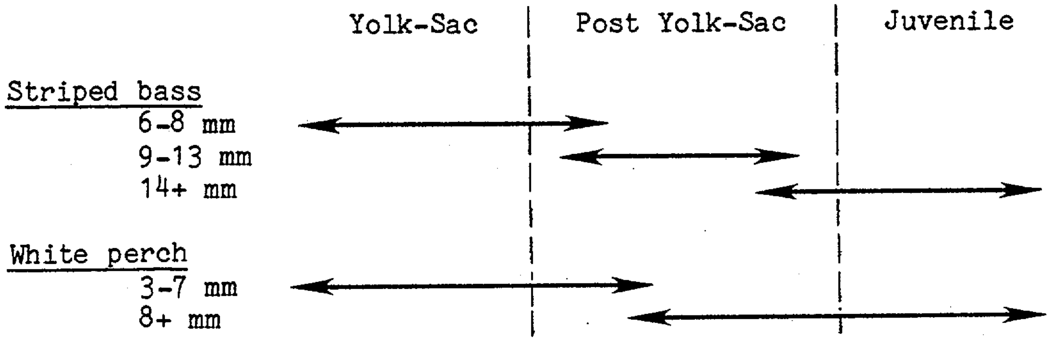


( ) Denotes less than 7 organisms.

Figure 6-47. (Cont.)

the Bowline Point plant, differences which may exist between pump-operating modes are not strong or consistent. This may be the result of differences in the relative magnitude of the various mechanical stresses among pump modes or differential sensitivity of various length groups to these stresses.

Variability of survival among 1-mm length intervals was evaluated by partitioning the G value (Tables P-5 - P-7) and examination of the life stage length-frequency histograms (Appendix O). Statistical partitioning indicates that the 1-mm length intervals can generally be pooled into three and two groups for striped bass and white perch, respectively. While some overlap and slight differences occur in these statistically observed intervals between intake and discharge or initial and 24-hour data, the length-frequency histograms indicate that data pooled over the following generally homogeneous length intervals will approximate those entrainable life stages historically used in impact analysis:



Temperature, length, and pump mode are significant factors in survival of entrained striped bass (Figure 6-48). The marginal and partial associations for a four-way multidimensional contingency analysis (Brown 1976) have been used to evaluate the relative magnitude of the effects of these variables on entrainment survival. The preferable hierarchical model to fit the data (Table 6-36) includes the full third-order interaction length x pump mode x temperature (LPT) plus the second-order factors length x survival (SL) and temperature x survival (TS). While the pump mode x survival (PS) interaction is significant (Table 6-36) the simpler model (LPT, LS, TS) provides a fit with no significant deviation from the full fourth-order model. If the pump x survival interaction is substituted for either the length or temperature effect (i.e., models LPT, LS, PS, or LPT, PS, TS) the resulting model will deviate significantly from the full four-factor model which indicates that pump operating mode is of less importance to striped bass entrainment survival than length and temperature. However, the most important interaction in describing the variation observed in these data is the unbalanced distribution of organisms by length among temperatures and pump modes (Table 6-37). That is, at discharge temperatures of 30.0 C most of the fish collected at two- and three-pump full operation were juveniles. Below 30 C most fish collected at the predominant two-pump operation were the more sensitive yolk-sac larvae. This distribution occurs because the throttled mode is generally used through early spring when ambient temperatures are low; as river temperatures increase, the mode is changed to two-pumps full and then three-pumps full by mid-summer. Since spawning of white perch and striped bass occurs during a relatively short period in the spring, few large larvae are found during two-throttled operation. Growth increases as ambient temperature increases through early summer; therefore, few small

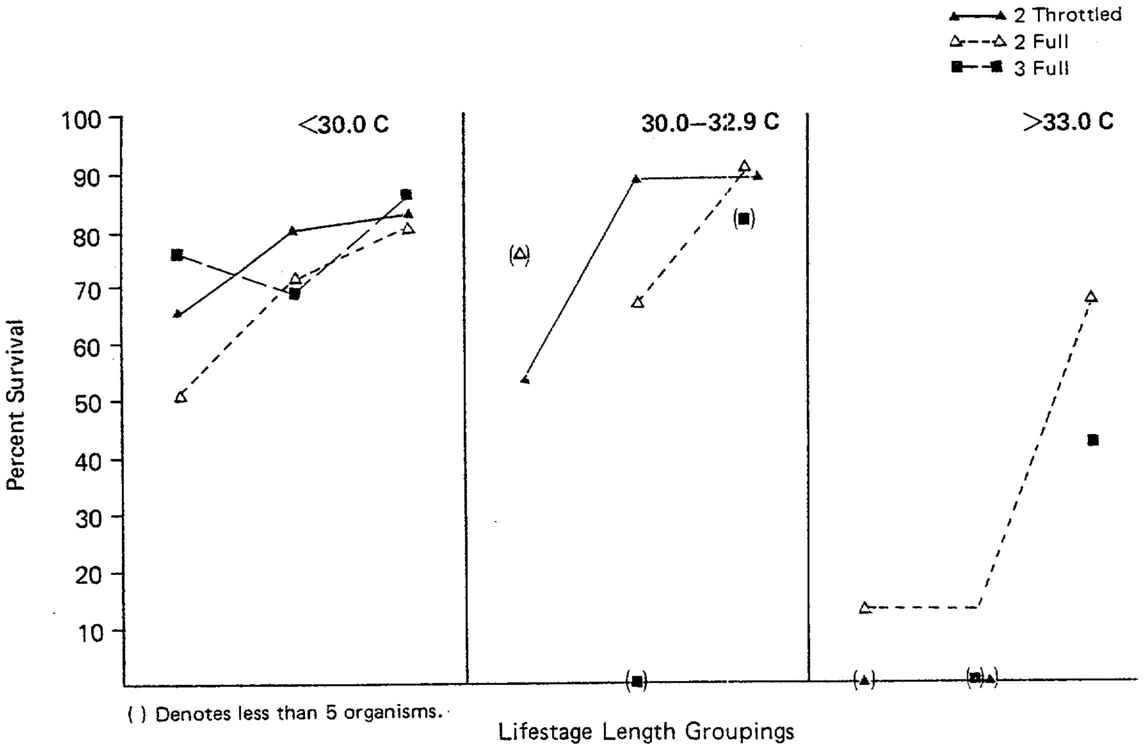


Figure 6-48. Survival by length group, temperature, and pump mode for striped bass collected at the Bowline Point plant discharge, 1975–1978.

TABLE 6-36 RESULTS OF MULTIDIMENSIONAL CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG LENGTH, PUMP MODE, TEMPERATURE, AND SURVIVAL OF STRIPED BASS COLLECTED AT THE BOWLINE POINT PLANT DISCHARGE USED TO EVALUATE THE RELATIVE MAGNITUDE OF THE EFFECTS OF THE FOUR FACTORS AND THEIR INTERACTIONS

	df	Marginal Association	Partial Association
Length x survival (LS)	2	58.51***	67.83***
Pump mode x survival (PS)	2	10.76**	13.13**
Temperature x survival (TS)	2	45.53***	46.43***
Length x temperature (LT)	4	324.77***	258.73***
Length x pump mode (LP)	4	153.74***	89.17***
Temperature x pump mode (TP)	4	103.58***	30.59***
Length x pump mode x survival (LPS)	4	9.77*	5.86
Length x temperature x survival (LTS)	4	4.27	5.83
Temperature x pump mode x survival (TPS)	4	6.67	2.13
Length x pump mode x temperature (LPT)	8	29.65***	29.43***
Length x pump mode x temperature x survival (LPTS)	8	3.13	3.13

Selected Model	Effect Added	x		df	Probability
LP, LT, PT, S		170.98(a)		34	<0.001
LPT,X		141.34		26	<0.001
	λ^{LPT}		29.64(b)	8	<0.001
LPT, LS		82.82		24	<0.001
	λ^{LC}		58.52	2	<0.001
LPT, LS, PS		65.95		22	<0.001
	λ^{CP}		16.87	2	<0.001
LPT, LPS		56.18		18	<0.001
	λ^{LpC}		9.77	4	<0.05
LPT, LS, TS		32.64		22	0.067
	λ^{CT}		33.31	2	<0.001
LPT, LS, TS, PS		19.53		20	0.488
	λ^{CP}		13.11	2	<0.01
LPT, LPS, TS		10.71		16	0.827
	λ^{CT}		45.47	2	<0.001

(a) Test-of-fit for selected model to data in full fourth-order model.

(b) Reduction in χ^2 which results from added effect (λ).

Note: * denotes $0.05 \geq p > 0.01$
** denotes $0.01 \geq p > 0.001$
*** denotes $0 \leq 0.001$

TABLE 6-37 DISTRIBUTION OF ORGANISMS USED IN MULTIDIMENSIONAL CONTINGENCY ANALYSIS OF INDEPENDENCE AMONG LENGTH, PUMP MODE, TEMPERATURE, AND SURVIVAL OF STRIPED BASS COLLECTED AT THE BOWLINE POINT PLANT DISCHARGE, 1975-1978

Temperature (C)	Pump Mode	Condition	Length (mm) 4-8	9-13	14+
<30	2 Throttled	Live	159	68	19
		Dead	84	17	4
	2 Full	Live	219	160	70
		Dead	211	65	17
	3 Full	Live	19	27	12
		Dead	6	12	2
30-32.9	2 Throttled	Live	8	8	8
		Dead	7	1	1
	2 Full	Live	3	14	56
		Dead	1	7	6
	3 Full	Live	0	0	40
		Dead	0	1	9
≥33	2 Throttled	Live	0	0	0
		Dead	1	1	0
	2 Full	Live	2	2	12
		Dead	13	13	6
	3 Full	Live	0	0	7
		Dead	0	2	10

larvae are found when three-pump operation begins. Few white perch or Atlantic tomcod were collected above their lethal thresholds (30 C and 18 C, respectively); therefore, no additional evaluation of thermal effects could be performed for those species.

Estimates of entrainment survival (the ratio of discharge to intake survival, S_e) by life stage typically exceed 80 percent for striped bass and 49 percent for white perch (Table 6-38). Generally no significant ($p > 0.05$) differences were found between initial and 24-hour S_e values which supports the previous conclusion based on analysis of the survival curves that no latent entrainment mortality occurs for striped bass. Furthermore, differences in entrainment survival among pump modes were not significant for post yolk-sac larvae (89-100 percent) and juveniles (88-94 percent), while survival for yolk-sac larvae collected at two-pumps full (66 percent) was significantly ($0.05 > p > 0.01$) less than at the two-throttled and three-pumps full modes (83-96 percent). Latent effects analysis indicated that for white perch the S_e values estimated from 24-hour data were most appropriate to account for latent entrainment mortality. The 24-hour S_e values were approximately 25 percent less than initial estimates (Table 6-38). Similar to striped bass, entrainment survival exhibited no significant differences between pump modes for post yolk-sac larvae and juveniles (73 to 78 percent).

Entrainment survival for Atlantic tomcod was 93.2 percent. The majority of the tomcod were collected as yolk-sac and post yolk-sac larvae between 6 and 8 mm under the two-pumps throttled mode.

The above entrainment survival estimates are useful for entrainment impact analysis; however, considering the significant effect of length on survival, a procedure which provides estimates based on length may be more applicable as input to predictive impact models in conjunction with other population parameters [e.g., natural mortality estimates (TI 1980a)] which are available by length. For both striped bass and white perch, linear regressions of survival on length for the intake and discharge station were highly significant ($p \leq 0.01$) with r^2 values that generally exceed 0.600 (Table 6-39). As observed previously, differences in survival between pump modes are small and the regression for both two-pump operating modes combined provides good fit of the data (F was significant at $p < 0.001$).

The S_e curve predicted from the fitted linear functions for intake and discharge clearly reflect the effect of length on survival and the latent effect of entrainment on survival of white perch. The curves for initial and 24 hours differ by 18-31 percent for white perch (Figure 6-49), but by only 2 to 9 percent for striped bass. Striped bass showed a linear increase in survival from 60 to 100 percent survival for larvae from 4 to 14 mm. Twenty-four hour survival of white perch, on the other hand, increased sharply from 0 percent for 3-mm larvae to approximately 60 percent at 7 mm; survival continued to increase more gradually to 80 percent for 15-mm fish.

The life stage S_e values (Table 6-38) generally provide an average survival estimate for the length interval which will underestimate survival for the larger organisms in that interval. The S_e values for striped bass yolk-sac and post yolk-sac larvae (Table 6-38) are higher than the estimate for the midpoint of the appropriate length intervals on the S_e/length curve (Figure 6-49). However, the life stage estimates are less than the predicted values

TABLE 6-38 MECHANICAL ENTRAINMENT SURVIVAL ESTIMATES(a) (S_e) FOR STRIPED BASS, WHITE PERCH, AND ATLANTIC TOMCOD COLLECTED AT THE BOWLINE POINT PLANT

		Entrainment Survival (S_e%)					
		Initial			24 Hours (b)		
Species	Pump Mode	YSL(c)	PYS	JUV	YSL	PYS	JUV
Striped bass	2T	82.5± 4.5	100.0± 7.6	90.1± 9.9	66.9± 6.8	97.2± 9.5	85.4±10.1
	2F	65.8± 3.6	91.3± 6.1	87.8± 6.0	58.9± 5.3	76.0± 6.8	82.8± 6.2
	3F	95.9±11.1	88.9±10.6	93.5±11.0	100.0±18.1	95.0±12.3	85.7±12.5
	Combined	81.4± 4.1	94.3± 4.8*	90.5± 5.2*	88.3± 6.8	89.4± 5.6	84.6± 5.7
White perch	2T	100.0±20.9	100.0± 6.4	(d)	71.8±28.4	78.2±10.1	(d)
	2F	49.8± 6.1	73.4± 8.5	(d)	26.2± 6.4	73.1±12.4	(d)
	3F	--(e)	--	--	--	--	--
	Combined	78.0±10.8	88.9± 5.3	(d)	49.0±14.5*	75.7± 8.0*	(d)
Atlantic tomcod	Combined	(f)	93.2± 2.7*	(f)	(f)	100.0± 3.9	(f)

(a) Includes striped bass and white perch collected below 30.0 C and Atlantic tomcod collected below 18.0 C.
(b) Based on 24-hour non-normalized data; includes initial and latent (if observed) effects.
(c) YSL = yolk-sac larvae through transition (4-8 mm for striped bass and 3-7 mm for white perch).
PYS = post yolk-sac larvae (9-13 mm for striped bass and 8+ mm to include juveniles for white perch).
JUV = juvenile and late post yolk-sac larvae (14+ mm for striped bass).
(d) JUV estimate is the same as PYS estimate for white perch.
(e) No estimate because less than 10 organisms collected at either intake, discharge, or both stations.
(f) No length effect observed for Atlantic tomcod; majority of organisms collected as YSL and PYS between 6 and 8 mm.

Note: * denotes best estimate of entrainment survival for species and life stage.

TABLE 6-39 SUMMARY OF REGRESSION ANALYSES USED TO FIT FUNCTIONS TO LENGTH-SURVIVAL DATA FOR STRIPED BASS AND WHITE PERCH COLLECTED AT THE BOWLINE POINT PLANT INTAKE AND DISCHARGE

Species	Time	Mode	R	R^2	df	F	p	a	b
Striped bass (< 30.0 C)	Initial	I	0.2104	0.0442	1, 8	0.370	0.56	0.769	0.004
		2F	0.9097	0.8275	1, 10	47.971	<0.001	0.269	0.038
		2T	0.7500	0.5625	1, 8	10.285	0.012	0.471	0.028
		2F + 2T	0.7772	0.6040	1, 20	30.502	<0.001	0.345	0.033
	24-hr.	I	0.9132	0.8340	1, 11	55.257	<0.001	0.239	0.042
		2F	0.9686	0.9382	1, 10	151.896	<0.001	-0.048	0.053
		2T	0.8648	0.7478	1, 8	23.722	0.001	0.039	0.054
		2F + 2T	0.9021	0.8138	1, 20	87.419	<0.001	0.008	0.052
White perch (< 30.0 C)	Initial	I	0.8741	0.7640	1, 10	32.372	<0.001	0.075	0.063
		2F	0.9653	0.9319	1, 8	109.452	<0.001	-0.123	0.969
		2T	0.8187	0.6702	1, 10	20.323	0.001	0.078	0.062
		2F + 2T	0.9370	0.8780	1, 20	143.984	<0.001	-0.155	0.079
	24-hr.	I	0.9665	0.9341	1, 11	155.907	<0.001	-0.095	0.059
		2F	0.8811	0.7763	1, 8	27.764	0.001	-0.195	0.054
		2T	0.7518	0.5652	1, 8	10.400	0.012	-0.077	0.045
		2F + 2T	0.9056	0.8201	1, 18	82.063	<0.001	-0.197	0.055

Note: R = correlation coefficient
R^2 = coefficient of determination
df = degrees of freedom
F = F-statistic
p = probability
a = y intercept
b = regression coefficient

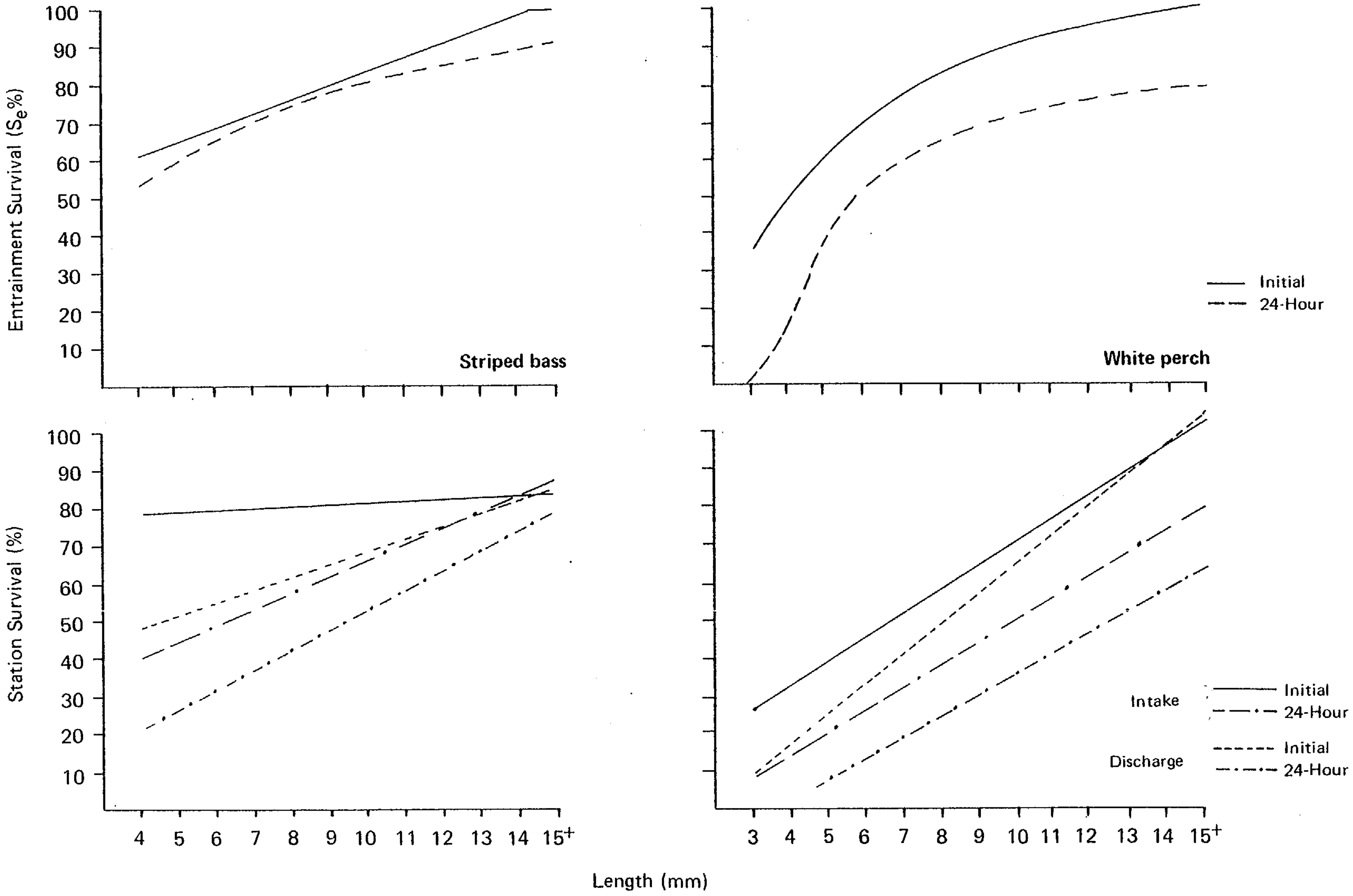


Figure 6-49. **Entrainment survival by length calculated with the intake and discharge survival values predicted by linear regression.**

for larvae and juveniles greater than 13 mm, and it is these larger organisms which are relatively more important to overall year-class strength. The life stage estimates for white perch do not reflect the sharp increase in survival observed for 3- to 7-mm fish on the predictive curve. Also, while the midpoint of the curve for 8- to 15-larvae is approximately the same as the S_e for post yolk-sac and juvenile white perch (75.7 percent, Table 6-38), the life stage estimate is less than the curve for larvae greater than 11 mm (Figure 6-49).

The results of the preceding analysis of entrainment survival data collected between 1975 and 1979 at the Bowline Point plant can be summarized as follows: Initial survival was found to be indicative of the total effect of entrainment for striped bass. The sensitivity of striped bass to entrainment stress decreased as length increased, such that survival of mechanical stresses (entrainment at discharge temperatures less than 30.0 C) exceeded 90 percent for those length groups which are most critical to year-class strength (late post yolk-sac and older--greater than 11 mm). The mode of circulator pump operation had some effect on survival for smaller larvae (less than 8 mm). While survival at two-pumps throttled was significantly greater than at two-pumps full for these smaller larvae, the differences between the two modes were not significant for larger larvae.

In contrast to striped bass, the full effect of entrainment on white perch is best estimated using the 24-hour data. The effect of length on survival was more pronounced for white perch than for striped bass. Again, differences in survival for the mechanical effects of two-pumps full versus two-pumps throttled operating mode were apparent only for larvae less than 8 mm.

No consistent decrease in mortality as a result of thermal exposure was observed for striped bass or white perch collected between 30 and 33 C. However, sharp decreases in survival did occur above 33 C in the range of the laboratory predicted median thermal tolerance limit (TL50--the temperature at which 50 percent of the organisms are expected to survive). Similar to the response of larvae to mechanical stresses observed in these field studies, laboratory studies have shown an increase with length in the resistance of larvae to thermal stress (Cada et al. 1980, EA 1978b, 1979b). This fact is important for an evaluation of entrainment impact at the Bowline Point plant since few larvae are collected near or above 33 C and most of those organisms are in the larger length intervals (i.e., late post yolk-sac larvae and juveniles). That is, the susceptibility of entrained striped bass and white perch to thermally-induced mortality is negligible.

Few Atlantic tomcod were collected above their incipient lethal temperatures and survival of mechanical stresses during entrainment exceeded 93 percent.

REFERENCES

Bath, D. 1974. New York University egg and larval seminar. Unpublished.

Bayless, J. D. 1972. Artificial propogation and hybridization of striped bass, Morone saxatilis (Walbaum). South Carolina Wildlife Resources Dept.

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish and Wildlife Serv. Fish. Bull. 74.

Booth, R. A. 1967. A description of the larval stages of the tomcod, Microgadus tomcod, with comments on its spawning ecology. Ph.D. Thesis, Univ. Connecticut.

Brown, M. B. 1976. Screening Effects in Multidimensional Contingency Tables. Appl. Statist. 25(1):37-46.

Cada, G. F., J. S. Suffern, K. D. Kumar, and J. A. Solomen. 1980. Investigations of entrainment mortality among larval and juvenile fishes using a power plant simulator, in Issues Associated with Impact Assesment, proceedings of The Fifth National Workshop on Entrainment and Impingement (L. D. Jensen, ed.), Ecological Analysts, Inc., Sparks, Md.

Chambers, J. R., J. A. Musick, and J. Davis. 1976. Methods of distinguishing larval alewife from larval blueback herring. Chesapeake Sci. 17:93-100.

Chappelle, E. W., G. L. Picciolo, C. A. Curtis, E. A. Knust, D. A. Nibley, and R. B. Vance. 1975. Laboratory procedures manual for the firefly luciferase assay for adenosine triphosphate (ATP). X-726-75-1 Goddard Space Flight Center, Greenbelt, Md.

Cianci, J. M. 1969. Larval development of the alewife Alosa pseudoharengus Wilson and the glut herring Alosa aestivalis Mitchell, M.S. Thesis, Univ. of Connecticut.

Dixon, W. J. and M. B. Brown, eds. 1977. BMDP-1977. Biomedical Computer Programs P-Series. University of California Press.

Doroshev, S. I. 1970. Biological features of the eggs, larval, and young of the striped bass (Roccus saxatilis Walbaum) in connection with the problem of its acclimatization in the USSR. J. Ichthiology 10:236-247.

Dovel, W. L. and J. R. Edmunds. 1971. Recent changes in striped bass spawning sites and commercial fishing areas in Upper Chesapeake Bay; possible incluencing factors. Chesapeake Sci. 12:33-39.

Ecological Analysts, Inc. 1976. Bowline Point Generating Station Entrainment Survival and Abundance Studies. 1975 Annual Interpretative Report. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1977a. A Review of Entrainment Study Methodologies: Abundance and Survival. Prepared for Empire State Electrical Energy Research Corp.

Ecological Analysts, Inc. 1977b. Bowline Point Generating Station Entrainment and Impingement Studies. 1976 Annual Report. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1977c. The effects of intakes and associated cooling water systems on phytoplankton and aquatic invertebrates of the Hudson River. Prepared for Central Hudson Gas & Electric Corporation, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1977d. Bowline Point Generating Station Dye Recirculation Study. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1978a. Bowline Point Generating Station 316(a) Demonstration. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1978b Hudson River Thermal Effects Studies for Representative Important Species. Final Report. Prepared for Central Hudson Gas & Electric Corporation; Consolidated Edison Company of New York, Inc.; and Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1978c. Bowline Point Generating Station Entrainment Abundance Studies. 1977 Annual Report. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1978d. Bowline Point Generating Station Entrainment Survival Studies. 1977 Annual Report. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1979a. Bowline Point Generating Station Entrainment Abundance and Survival Studies. 1978 Annual Report. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1979b. Effects of Heat Shock on Predation of Striped Bass Larvae by Yearling White Perch. Prepared for Central Hudson Gas & Electric Corporation, Consolidated Edison Company of New York, Inc., Orange and Rockland Utilities, Inc., and Power Authority of the State of New York.

Ecological Analysts, Inc. 1980a. Roseton Generating Station Entrainment Survival Studies. 1978 Annual Report. Prepared for Central Hudson Gas & Electric Corporation.

Ecological Analysts, Inc. 1980b. Danskammer Point Generating Station Entrainment Survival Studies. 1978 Annual Report. Prepared for Central Hudson Gas & Electric Corporation.

Fleiss, J. L. 1973. Statistical Methods for Rates and Proportions, pp. 92-96. John Wiley and Sons, N.Y.

Hildebrand, S. F. and W. C. Schroeder. 1928. Fishes of Chesapeake Bay. Bull. U.S. Bur. Fish. 43.

Hollander, M. and D. A. Wolfe. 1973. Nonparametric Statistical Methods. John Wiley and Sons, N.Y.

Holm-Hansen, O. and C. R. Booth. 1966. The measurement of adenosine triphosphate in the ocean and its ecological significance. Limnol. Oceanogr. 11:510-519.

Jinks, S. M., T. Cannon, D. Latimer, L. Claflin, and G. Lauer. 1978. An Approach for the Analysis of Striped Bass Entrainment Survival at Hudson River Power Plants, in Fourth National Workshop on Entrainment and Impingement (L. D. Jensen, ed.). EA Communications, a Division of Ecological Analysts, Inc., Melville, N.Y.

Krester, W. A. 1968. Aspects of striped bass larvae Morone saxatilis captured in the Hudson River near Cornwall, N.Y. April-August 1968. Consolidated Edison Company of New York, Inc.

Lanza, G. R. and J. Cairns, Jr. 1972. Physio-morphological effects of abrupt thermal stress on diatoms. Trans. Amer. Micros. Soc. 19(3):276-298.

Lauer, G. J., W. T. Waller, D. W. Bath, W. Meeks, R. Heffner, T. Ginn, L. Zubarik, P. Bibko, and P. C. Storm. 1974. Entrainment Studies on Hudson River Organisms, in Proceedings of the Second Entrainment and Intake Screening Workshop (L. D. Jensen, ed.), p. 37-82.

Lawler, Matusky & Skelly Engineers (LMS). 1978. Bowline Point Generating Station. Hydrothermal analysis. Prepared for Orange and Rockland Utilities, Inc.

Leim, A. H. 1924. The life history of the shad (Alosa sapidissima) with special reference to the factors limiting its abundance. Contrib. Canadian Biol. 2(11):161-284.

Lippson, A. J. and R. L. Moran. 1974. Manual for Identification of early developmental stages of fishes of the Potomac River Estuary. Env. Tech. Center Martin Marietta Corp.

Loftus, M. E. and J. H. Carpenter. 1971. A fluorometric method for determining chlorophylls a, b, and c. J. Mar. Res. 29(3):319-338.

McFadden, J. T. 1977. Influence of Indian Point Unit 2 and other steam electric generating plants on the Hudson River estuary, with emphasis on striped bass and other fish populations. Prepared for Consolidated Edison Company of New York, Inc.

McGroddy, P. M. and R. L. Wyman. 1977. Efficiency of nets and a new device for sampling living fish larvae. J. Fish. Res. Board Can. 34:571-574.

Mansuetti, A. J. and J. D. Hardy, Jr. 1967. Development of fishes of the Chesapeake Bay region; an atlas of egg, larval, and juvenile stages. Natural Res. Inst., Univ. of Maryland. 202 pp.

Moreth, C. M. and C. S. Yentsch. 1970. A sensitive method for the determination of open ocean phytoplankton phycoerythrin pigments by fluorescence. Limnol. Oceanogr. 15(2):313-317.

Morgan, R. P., II. 1974. Testimony before Federal Power Commission, October 1974, Project No. 2338 (Cornwall). pp. 4, 735, 816.

Morgan, R. P., II, R. E. Ulanowicz, V. J. Rasin, Jr., L. A. Noe, and G. B. Gray. 1973. Effects of Water Movement on Eggs and Larvae of Striped Bass and White Perch. Appendix 12 of Hydrographic and Ecological Effects of Enlargement of the Chesapeake and Delaware Canal. NRI 73-111, 28 pp.

Morgan, R. P., II, R. E. Ulanowicz, V. J. Rasin, Jr., L. A. Noe, and G. B. Gray. 1976. Effects of shear on eggs and larvae of striped bass, *Morone saxatilis*, and white perch, *M. americana*. Trans. Am. Fish. Soc. 105(1):149-154.

New York University (NYU). 1973. Effects of Entrainment by the Indian Point Power Plant on Biota in the Hudson River Estuary. Progress Report for 1971 and 1972. Prepared for Consolidated Edison Company of New York, Inc.

New York University (NYU). 1974. Effects of Entrainment by the Indian Point Power Plant on Hudson River Estuary Biota. Progress Report for 1973. Prepared for Consolidated Edison Company of New York, Inc.

New York University (NYU). 1975. Effects of Changes in Hydrostatic Pressure on Some Hudson River Biota. Progress Report for 1975. New York Univ. Medical Center, Institute of Environmental Medicine, Laboratory for Environmental Studies, New York, N.Y. Prepared for Consolidated Edison Company of New York, Inc.

Orange and Rockland Utilities, Inc. 1977. Bowline Point Generating Station: Near-field effects of once-through cooling systems operation on Hudson River biota.

Polgar, T. T. 1977. Striped bass ichthyoplankton abundance, mortality and production estimation for the Potomac River population, pp. 110-126, *in* Proceedings of the Conference on Assessing the Effects of Power-Plant-Induced Mortality on Fish Populations (W. Van Winkle, ed.). Pergamon Press, N.Y.

Rathjen, W. F. and L. C. Miller. 1957. Aspects of the early life history of the striped bass (*Roccus saxatilis*) in the Hudson River. N.Y. Fish and Game J. 4:43-60.

Scotten, L. N., R. E. Smith, N. S. Smith, K. S. Price, and D. P. de Sylva. 1973. Pictorial guide to fish larvae of Delaware Bay with information and bibliographies useful for the study of fish larvae. College Marine Studies, Univ. Delaware, Delaware Bay Rpt. Ser. 7. 206 pp.

Sokal, R. R., and F. J. Rohlf. 1969. Biometry. The Principles and Practice of Statistics in Biological Research. W. H. Freeman and Co.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and Procedures of Statistics. McGraw Hill, New York.

Texas Instruments, Inc. 1978. 1975 Year-class Report for the Multiplant Impact Study of the Hudson River Estuary. Prepared for Consolidated Edison Company of New York, Inc.

Texas Instruments, Inc. 1979. 1976 Year-class Report for the Multiplant Impact Study of the Hudson River Estuary. Prepared for Consolidated Edison Company of New York, Inc.

Texas Instruments, Inc. 1980a. 1978 Year-class Report for the Multiplant Impact Study of the Hudson River Estuary. Prepared for Consolidated Edison Company of New York, Inc.

Texas Instruments, Inc. 1980b. 1977 Year-class Report for the Multiplant Impact Study of the Hudson River Estuary. Prepared for Consolidated Edison Company of New York, Inc.

Texas Instruments, Inc. 1980c. Preliminary 1979 year-class data summaries provided by letter from Mr. Thomas E. O'Connor of Consolidated Edison Company of New York, Inc. 10 September 1980.

Wang, J. C. S. and R. J. Kernehan. 1979. Fishes of the Delaware Estuaries: A Guide to Early Life Histories. EA Communications.

APPENDIX A

PHYSICOCHEMICAL DATA
BOWLINE POINT PLANT INTAKE, 1979

TABLE A-1 DAILY WATER TEMPERATURE, CONDUCTIVITY, DISSOLVED OXYGEN, AND pH MEASURED AT THE BOWLINE POINT PLANT INTAKE, 1979

Date	Temp. (C)	Cond.	DO (mg/ℓ)	pH
3 JAN	3.4	1,660	5.4	8.2
5 JAN	1.3	180	5.3	8.4
8 JAN	2.0	60	6.7	8.1
12 JAN	1.0	140	--	7.0
16 JAN	-0.1	40	9.0	8.3
19 JAN	-0.7	30	9.4	7.8
22 JAN	-0.6	88	9.0	7.7
26 JAN	-0.3	42	10.1	7.7
30 JAN	0.0	140	--	8.0
1 FEB	2.0	130	12.7	8.0
7 FEB	1.0	120	13.3	8.0
9 FEB	1.0	650	13.4	8.0
13 FEB	0.5	1,700	12.6	8.0
16 FEB	0.0	1,800	12.4	8.0
20 FEB	1.0	1,300	12.5	8.0
23 FEB	2.0	2,300	12.0	8.0
2 MAR	2.0	250	11.6	8.0
5 MAR	2.0	160	12.2	8.0
6 MAR	1.0	125	13.1	7.3
7 MAR	2.0	130	13.0	8.0
8 MAR	3.0	103	11.6	7.2
9 MAR	2.0	120	12.8	6.0
12 MAR	2.0	100	12.5	6.0
13 MAR	0.4	90	12.7	7.1
14 MAR	1.5	91	12.0	7.2
15 MAR	1.3	88	11.9	7.2
16 MAR	0.6	84	11.6	7.3
19 MAR	1.8	87	11.4	7.6
20 MAR	0.8	86	11.8	7.6
21 MAR	3.4	89	12.2	7.2
22 MAR	3.9	165	10.4	7.3
23 MAR	4.0	279	10.8	7.3
26 MAR	4.9	211	10.4	7.5
27 MAR	3.9	119	10.5	7.3
28 MAR	3.6	105	10.8	7.4
29 MAR	4.5	110	10.2	7.2
30 MAR	5.1	112	10.4	7.2
3 APR	7.3	121	9.1	7.4
12 APR	6.2	479	9.4	7.7
13 APR	6.5	296	9.9	7.4
17 APR	7.0	111	9.3	7.9
19 APR	7.0	101	9.4	7.9
23 APR	9.0	106	9.6	7.9

Note: Dashes (--) indicate no data available.

TABLE A-1 (CONT.)

Date	Temp. (C)	Cond.	DO (mg/ℓ)	pH
27 APR	10.5	114	8.8	7.7
2 MAY	11.4	126	8.4	7.4
3 MAY	11.7	127	8.1	7.5
4 MAY	12.0	132	8.5	7.8
7 MAY	13.3	137	8.8	8.0
17 MAY	18.1	920	7.6	7.6
21 MAY	17.6	639	7.3	7.3
24 MAY	17.7	1,151	6.4	7.3
29 MAY	18.0	426	7.1	7.8
31 MAY	18.7	202	6.9	7.2
4 JUN	19.8	140	7.3	7.4
7 JUN	21.3	1,850	7.8	7.5
11 JUN	18.0	3,400	7.0	--
12 JUN	20.5	3,850	6.5	7.3
13 JUN	20.3	3,000	6.8	7.6
14 JUN	20.7	2,200	7.3	7.3
15 JUN	21.1	1,730	7.0	7.3
16 JUN	21.8	1,440	--	7.3
18 JUN	22.8	1,250	7.0	7.9
19 JUN	22.8	890	7.0	7.4
20 JUN	22.9	1,130	6.8	7.4
21 JUN	23.5	1,160	7.0	7.6
22 JUN	23.2	1,870	6.8	7.3
25 JUN	21.8	1,870	6.9	7.9
26 JUN	21.8	2,140	7.3	7.5
27 JUN	22.1	2,610	7.1	7.5
28 JUN	22.3	2,560	7.1	7.5
29 JUN	22.6	2,350	7.4	7.3
30 JUN	23.6	2,380	8.2	7.7
1 JUL	23.6	2,620	7.3	7.5
2 JUL	23.2	2,760	6.8	7.4
3 JUL	23.4	3,060	6.5	7.4
5 JUL	22.3	4,460	6.4	7.5
6 JUL	22.0	5,900	6.3	7.3
7 JUL	21.9	6,560	6.4	7.4
8 JUL	22.6	7,660	6.8	7.4
9 JUL	23.1	8,350	6.8	7.4
10 JUL	23.0	9,340	6.3	7.2
11 JUL	23.5	8,820	6.1	7.5
12 JUL	24.2	9,200	6.0	7.4
13 JUL	23.9	8,640	5.6	7.1
16 JUL	27.5	8,530	5.8	7.5
18 JUL	26.3	7,710	5.5	7.7
23 JUL	26.4	8,650	4.7	7.5
26 JUL	27.6	8,390	5.7	7.5
31 JUL	29.1	8,140	5.2	7.6
6 AUG	28.9	10,350	5.7	7.4
13 AUG	25.6	8,490	6.2	7.6

TABLE A-1 (CONT.)

Date	Temp. (C)	Cond.	DO (mg/ℓ)	pH
17 AUG	23.3	7,500	6.3	7.7
19 AUG	24.0	8,290	6.2	7.8
20 AUG	25.2	8,690	6.4	7.4
21 AUG	25.3	9,230	6.4	7.5
23 AUG	25.9	9,600	7.2	7.7
24 AUG	24.9	10,010	5.8	7.5
26 AUG	25.7	9,040	5.8	7.7
27 AUG	25.8	8,920	6.5	7.5
28 AUG	25.6	9,360	6.2	7.7
29 AUG	26.6	8,710	6.4	7.4
31 AUG	25.9	8,960	5.3	7.5
5 SEP	27.2	10,120	6.9	7.9
6 SEP	26.7	10,120	5.8	7.6
7 SEP	26.2	9,710	5.5	7.4
8 SEP	25.7	7,880	5.2	7.4
9 SEP	24.2	6,060	5.5	7.4
10 SEP	23.9	5,280	5.9	7.5
11 SEP	24.7	4,890	6.0	7.5
12 SEP	25.5	4,060	6.6	7.6
14 SEP	24.9	4,170	5.7	7.6
17 SEP	24.5	3,020	6.1	8.0
19 SEP	23.4	3,150	6.1	7.7
20 SEP	21.2	2,890	6.3	7.5
21 SEP	21.3	3,210	6.5	7.7
22 SEP	21.6	3,010	6.4	7.6
24 SEP	19.5	2,530	6.7	7.5
25 SEP	21.1	2,740	6.4	7.5
26 SEP	20.6	2,490	6.4	7.5
27 SEP	20.5	2,490	6.1	7.5
28 SEP	20.9	2,570	6.2	7.5
1 OCT	21.1	3,870	5.7	7.8
2 OCT	20.7	4,230	5.4	7.4
3 OCT	21.3	4,930	5.6	7.4
4 OCT	20.3	5,240	5.6	7.3
5 OCT	20.5	4,610	5.7	7.3
6 OCT	19.4	3,770	6.7	7.5
8 OCT	18.3	1,770	6.3	7.4
9 OCT	17.8	640	6.2	7.6
10 OCT	17.1	440	6.3	7.4
11 OCT	16.6	430	6.4	7.5
12 OCT	16.1	375	6.5	7.6
15 OCT	15.3	160	6.8	8.1
16 OCT	15.5	230	6.5	7.7
17 OCT	15.5	430	6.6	7.6
18 OCT	15.4	570	6.6	7.6
19 OCT	15.6	990	6.6	7.4
20 OCT	16.1	1,610	6.8	7.5
22 OCT	16.5	2,230	6.4	7.5

TABLE A-1 (CONT.)

Date	Temp. (C)	Cond.	DO (mg/ℓ)	pH
24 OCT	16.3	2,280	6.5	7.3
25 OCT	15.8	2,215	6.4	7.4
26 OCT	15.2	1,800	6.7	7.5
29 OCT	13.7	1,410	6.7	8.2
30 OCT	13.5	1,260	6.8	7.5
31 OCT	13.4	1,230	6.8	7.5
1 NOV	12.7	1,500	7.0	7.5
2 NOV	13.3	1,855	6.9	7.4
3 NOV	14.2	2,070	6.8	7.4
5 NOV	11.0	1,010	7.2	7.5
6 NOV	12.5	760	6.9	7.3
7 NOV	12.6	610	6.7	7.2
8 NOV	12.2	480	6.9	7.3
9 NOV	11.9	340	6.9	7.2
12 NOV	11.0	130	7.1	7.3
13 NOV	11.0	140	7.2	7.4
14 NOV	10.5	100	7.2	7.3
15 NOV	9.6	1,530	7.2	7.3
16 NOV	9.1	2,470	7.5	7.4
19 NOV	11.0	4,100	--	--
20 NOV	8.0	4,300	--	--
21 NOV	11.0	3,000	--	--
26 NOV	13.0	1,800	--	--
27 NOV	13.0	2,500	--	--
28 NOV	11.0	1,055	12.6	--
29 NOV	8.5	648	10.6	--
30 NOV	7.2	305	10.3	--
1 DEC	7.0	206	10.2	--
3 DEC	5.1	157	10.7	--
4 DEC	5.8	152	10.4	--
5 DEC	6.2	152	10.9	--
6 DEC	6.0	152	10.7	--
7 DEC	6.2	151	9.6	--
8 DEC	4.4	132	10.8	--
10 DEC	4.4	139	10.6	--
11 DEC	7.5	175	--	--
12 DEC	6.5	240	--	--
13 DEC	6.4	148	10.3	--
14 DEC	5.8	241	10.4	--
16 DEC	5.2	2,347	9.3	--
17 DEC	4.1	2,970	10.5	--
18 DEC	3.3	3,655	10.4	--
19 DEC	2.9	3,520	10.7	--
20 DEC	3.1	3,278	11.1	--
21 DEC	2.5	2,878	10.9	--
26 DEC	4.7	2,259	11.9	--
27 DEC	6.2	1,918	9.5	--
28 DEC	4.0	866	11.1	--

APPENDIX B

PHYTOPLANKTON VIABILITY DATA, BOWLINE POINT PLANT 1975, 1976

TABLE B-1 INITIAL PHYTOPLANKTON PRODUCTIVITY AND CONDITION DATA COLLECTED AT THE BOWLINE POINT PLANT, 1975

		Temperature (C)			Primary Productivity (mg C/ℓ/hr)			Chlorophyll-a (μg/ℓ)			Density (1,000/ℓ)		
Date	Rep	Ambient	Discharge	ΔT	Intake	Discharge	Control	Intake	Discharge	Control	Intake	Discharge	Control
24 JUN	1	24.9	33.4	8.5	0.052	0.045	0.052	13.24	11.79	12.16	3,790.1	2,864.8	3,224.7
	2				0.059	0.052	0.049	12.70	12.16	12.34	4,535.2	2,980.0	3,358.2
25 JUN	1	24.9	33.2	8.3	0.045	0.045	0.054	12.52	12.52	13.06	3,682.1	2,346.5	2,504.9
	2				0.049	0.046	0.054	11.25	11.25	12.34	4,751.1	2,375.3	2,908.0
26 JUN	1	25.0	32.5	7.5	0.016	0.054	0.043	12.16	11.43	11.43	3,469.4	2,951.2	3,138.3
	2				0.048	0.049	0.025	11.61	11.25	11.61	2,555.3	2,735.2	2,944.0
30 JUN	1	25.0	33.3	8.3	0.011	0.025	0.026	6.89	6.53	7.07	1,498.1	1,137.8	1,599.4
	2				0.028	0.010	0.031	6.35	5.98	6.53	1,356.4	1,121.6	1,356.4
21 AUG	1	25.4	33.1	7.7	0.057	0.064	0.052	7.26	7.98	6.53	5,069.7	4,178.8	3,304.0
	2				0.095	0.058	0.053	10.52	7.07	5.80	7,758.4	4,945.5	3,919.7
22 AUG	1	25.8	33.4	7.6	0.068	0.048	0.044	8.16	6.89	5.80	6,446.4	4,653.9	5,069.7
	2				0.066	0.041	0.056	7.98	6.71	6.53	6,349.2	4,222.0	4,340.8
25 AUG	1	24.8	30.2	5.4	0.025	0.021	0.029	3.81	3.81	3.99	2,801.9	2,648.0	2,591.4
	2				0.027	0.020	0.027	4.17	3.99	4.71	3,001.6	2,559.0	2,364.6
26 AUG	1	25.2	30.9	5.7	0.027	0.023	0.023	5.26	4.17	4.35	3,282.6	2,627.3	3,150.1
	2				0.032	0.021	0.020	5.80	3.99	3.99	3,315.0	2,548.1	3,055.8
11 NOV	1	14.1	15.1	1.0	0.007	0.005	0.007	2.90	2.17	2.54	336.8	710.3	582.8
	2				0.007	0.007	0.006	2.90	1.99	2.72	665.0	480.8	514.8
12 NOV	1	13.4	15.2	1.8	0.008	0.002	0.007	3.81	0.99	3.26	563.9	216.9	238.0
	2				0.006	0.001	0.004	3.63	1.08	3.35	640.7	317.3	827.0
13 NOV	1	13.4	15.4	2.0	0.002	0.001	0.004	3.35	0.99	3.44	844.8	442.0	467.0
	2				0.003	0.002	0.003	2.99	0.99	3.35	469.5	443.6	378.8
14 NOV	1	12.6	15.5	2.9	0.005	0.002	0.006	2.17	0.63	1.45	442.0	207.2	446.8
	2				0.005	0.002	0.004	1.99	0.72	0.90	490.6	393.4	542.9

TABLE B-2 TWENTY-FOUR PHYTOPLANKTON PRODUCTIVITY AND CONDITION DATA COLLECTED AT THE BOWLINE POINT PLANT, 1975

		Primary Productivity (mg C/ℓ/hr)			Chlorophyll-*a* (μg/ℓ)			Density (1,000/ℓ)		
Date	Rep	Intake	Discharge	Control	Intake	Discharge	Control	Intake	Discharge	Control
24 JUN	1	0.046	0.050	0.002	21.05	21.78	16.69	8,865.2	8,152.5	8,465.6
	2	0.051	0.056	0.001	21.23	9.43	13.24	9,739.8	9,696.6	9,718.2
25 JUN	1	0.030	0.037	0.012	15.42	17.78	17.06	5,787.7	6,284.0	7,110.5
	2	0.021	0.063	0.024	11.61	20.69	17.24	5,766.1	9,410.5	5,377.4
26 JUN	1	0.053	0.073	0.064	15.97	18.15	15.24	8,962.3	9,286.3	7,061.9
	2	0.047	0.085	0.062	16.87	19.96	16.87	6,651.6	9,826.2	6,306.0
30 JUN	1	0.029	0.039	0.047	8.16	9.80	11.43	5,215.4	4,567.6	4,848.3
	2	0.032	0.039	0.051	9.25	10.34	11.43	5,755.3	4,707.9	5,388.2
21 AUG	1	0.100	0.086	0.080	9.98	9.80	11.97	13,216.8	12,536.5	12,374.5
	2	0.155	0.095	0.078	18.51	10.52	10.70	20,116.7	10,884.4	12,471.7
22 AUG	1	0.204	0.154	0.156	21.78	17.06	18.87	31,875.7	25,202.5	27,599.7
	2	0.167	0.166	0.189	23.59	13.06	14.15	30,385.6	24,295.5	21,704.0
25 AUG	1	0.054	0.055	0.052	6.17	10.34	11.25	11,208.3	9,718.2	10,528.1
	2	0.050	0.050	0.055	9.80	10.34	9.98	11,273.1	11,370.3	9,750.6
26 AUG	1	0.086	0.071	0.066	5.62	10.34	9.43	8,940.7	10,495.7	7,612.6
	2	0.096	0.068	0.052	10.52	9.98	9.61	9,718.2	8,552.0	8,228.1
11 NOV	1	0.006	0.005	0.004	4.17	2.45	3.17	383.7	1,420.5	514.8
	2	0.007	0.005	0.006	3.72	2.54	3.35	689.3	581.0	386.9
12 NOV	1	0.003	0.001	0.004	3.90	1.17	2.90	1,234.1	997.6	924.4
	2	0.002	0.000	0.003	3.90	0.99	3.26	1,328.1	615.2	888.0
13 NOV	1	0.006	0.001	0.006	2.99	1.08	3.26	410.2	540.7	391.8
	2	0.007	0.001	0.004	2.99	0.81	3.17	814.6	582.8	542.4
14 NOV	1	0.006	0.001	0.004	1.92	0.72	1.56	527.8	202.4	677.7
	2	0.005	0.001	0.004	1.92	0.65	2.17	1,130.4	453.3	696.2

TABLE B-3 INITIAL PHYTOPLANKTON PRODUCTIVITY AND CONDITION DATA COLLECTED AT THE BOWLINE POINT PLANT, 1976

		Temperature (C)			Primary Product (mg C/ℓ/hr)		ATP (μg/ℓ)		Density (1000/ℓ)		Autofluorescence (Percent Healthy)[a]			
Date	Rep	Ambient	Discharge	ΔT	Intake	Discharge	Intake	Discharge	Intake	Discharge	Intake		Discharge	
15 APR	1	10.4	17.4	7.0	0.000	0.001	0.071	0.091	399.9	283.3	72.8	(191)	72.0	(254)
	2				0.001	0.001	0.071	0.111	312.5	320.6	86.4	(257)	79.6	(211)
29 APR	1	11.0	20.5	9.5	0.001	0.002	0.058	0.047	391.8	302.8	87.6	(202)	76.7	(103)
	2				0.002	0.002	0.051	0.048	396.7	202.4	83.4	(199)	82.4	(244)
13 MAY	1	15.3	24.9	9.6	0.047	0.043	0.279	0.376	6,624.6	6,090.1	95.4	(1,000)	96.3	(870)
	2				0.046	0.045	0.365	0.362	8,325.3	5,733.7	92.4	(778)	91.1	(629)
27 MAY	1	16.1	26.1	10.0	0.024	0.025	0.207	0.226	3,844.1	3,320.2	86.4	(1,166)	69.2	(633)
	2				0.025	0.026	0.140	0.290	3,466.2	3,336.4	73.7	(662)	87.8	(891)
10 JUN	1	19.1	29.2	10.1	0.058	0.089	0.240	0.186	10,819.6	10,333.7	88.1	(1,094)	89.7	(679)
	2				0.146	0.084	0.297	0.211	9,637.2	8,454.8	90.8	(1,121)	83.8	(631)
24 JUN	1	23.2	32.9	9.7	0.095	0.096	1.295	0.958	8,876.0	5,042.7	84.2	(557)	80.8	(395)
	2				0.116	0.080	1.400	0.970	6,948.5	7,661.2	88.6	(571)	76.1	(527)
8 JUL	1	25.3	32.2	6.9	0.040	0.027	0.255	0.042	2,584.7	1,380.7	80.3	(431)	58.6	(326)
	2				0.041	0.028	0.114	0.083	2,720.8	1,275.4	70.5	(387)	60.8	(365)
22 JUL[b]	1	25.2	25.5	0.3	0.067	0.076	0.414	0.208	4,124.8	4,405.6	54.4	(373)	63.4	(350)
	2				0.076	0.066	0.426	0.311	4,276.0	4,513.6	78.3	(345)	74.7	(265)
17 AUG[b]	1	24.4	25.0	0.6	0.066	0.072	0.223	0.091	4,999.5	3,638.9	77.3	(427)	81.0	(457)
	2				0.071	0.075	0.143	0.107	5,258.6	3,736.1	72.7	(220)	82.7	(283)
26 AUG[b]	1	25.2	25.4	0.2	0.046	0.043	0.616	0.580	9,766.8	8,454.8	87.9	(471)	92.9	(454)
	2				0.066	0.059	0.850	0.399	10,268.9	8,616.8	83.5	(393)	91.9	(295)
16 SEP[b]	1	22.8	22.9	0.1	0.041	0.015	0.463	0.099	3,328.3	1,075.3	47.1	(382)	47.3	(520)
	2				0.025	0.013	0.452	0.119	3,020.6	968.5	50.8	(380)	36.7	(283)
30 SEP	1	19.6	28.1	8.5	0.012	0.011	0.067	0.044	1,187.7	341.0	31.5	(346)	28.6	(486)
	2				0.010	0.006	0.062	0.026	991.1	330.2	32.2	(326)	21.6	(393)
14 OCT	1	17.4	28.1	10.7	0.037	0.045	0.202	0.164	5,301.8	3,844.1	58.1	(353)	48.2	(394)
	2				0.042	0.050	0.277	0.123	4,556.8	3,671.3	65.5	(354)	60.6	(485)
28 OCT	1	11.0	20.7	9.7	0.036	0.032	0.404	0.243	5,652.8	4,470.4	76.6	(312)	50.9	(318)
	2				0.045	0.040	0.312	0.324	5,749.9	4,200.4	76.0	(458)	58.0	(383)
4 NOV	1	9.4	19.9	10.5	0.023	0.022	0.429	0.160	2,469.9	2,801.9	58.2	(311)	51.7	(466)
	2				0.024	0.022	0.202	0.182	3,295.9	2,729.0	62.4	(309)	60.2	(382)
18 NOV	1	6.8	19.4	12.6	0.004	0.004	0.066	0.260	544.0	429.0	13.9	(418)	22.4	(375)
	2				0.004	0.004	0.081	0.169	453.3	655.7	12.0	(326)	9.7	(351)

(a) Percent of those organisms alive classified as healthy; number in parentheses is N of sample.
(b) Unit 1 down, circulating pumps on.

TABLE B-4 TWENTY-FOUR HOUR PHYTOPLANKTON PRODUCTIVITY AND CONDITION DATA COLLECTED AT THE BOWLINE POINT PLANT, 1976

		Primary Productivity (mg C/ℓ/hr)		ATP (µg/ℓ)		Density (1,000/ℓ)		Autofluorescence Percent Healthy[a]			
Date	Rep	Intake	Discharge	Intake	Discharge	Intake	Discharge	Intake		Discharge	
15 APR	1	0.001	0.001	0.076	0.084			83.7	(257)	80.0	(285)
	2	0.001	0.001	0.045	0.056			77.2	(228)	80.2	(242)
29 APR	1	0.002	0.002	0.112	0.081			84.2	(273)	88.7	(486)
	2	0.002	0.004	0.085	0.112			79.8	(272)	91.8	(588)
13 MAY	1	0.065	0.060	0.834	0.381			81.8	(946)	91.4	(1,413)
	2	0.077	0.063	0.784	0.450			90.9	(1,503)	90.6	(1,228)
27 MAY	1	0.037	0.037	0.542	0.510			88.0	(623)	78.1	(562)
	2	0.057	0.036	0.490	0.394			77.1	(711)	89.8	(470)
10 JUN	1	0.141	0.108	1.052	0.602			94.3	(673)	90.4	(1,509)
	2	0.222	0.110	0.592	0.834			90.8	(795)	89.4	(1,584)
24 JUN	1	0.104	0.103	2.120	1.458			81.4	(784)	85.9	(780)
	2	0.126	0.088	1.190	1.354			83.1	(486)	84.3	(784)
8 JUL	1	0.058	0.031	1.134	0.399			85.3	(634)	71.6	(559)
	2	0.055	0.017	0.958	0.226			85.4	(663)	60.5	(430)
22 JUL[b]	1	0.129	0.115	3.480	1.92			89.2	(370)	79.7	(408)
	2	0.133	0.103	2.180	1.90	Not monitored		93.1	(291)	85.3	(395)
17 AUG[b]	1	0.055	0.050	1.204	0.412			80.0	(496)	81.4	(458)
	2	0.076	0.037	0.691	0.852			84.9	(676)	89.3	(422)
26 AUG[b]	1	0.031	0.034	1.974	4.946			88.7	(453)	81.6	(534)
	2	0.049	0.048	2.119	3.592			98.2	(565)	90.4	(666)
16 SEP[b]	1	0.051	0.020	1.018	0.373			33.3	(399)	35.0	(429)
	2	0.035	0.022	0.587	0.268			22.5	(395)	31.1	(363)
30 SEP	1	0.012	0.007	0.616	0.223			23.0	(426)	17.4	(421)
	2	0.008	0.006	0.411	0.237			18.3	(367)	11.5	(487)
14 OCT	1	0.050	0.029	0.858	0.245			41.8	(426)	79.3	(415)
	2	0.041	0.043	0.727	0.474			84.6	(622)	58.5	(472)
28 OCT	1	0.030	0.024	0.298	0.391			74.3	(478)	85.6	(472)
	2	0.034	0.025	0.505	0.662			63.3	(409)	59.2	(610)
4 NOV	1	0.019	0.018	0.314	0.371			69.6	(603)	49.9	(581)
	2	0.022	0.017	0.399	0.383			61.7	(371)	51.7	(493)
18 NOV	1	0.003	0.005	0.131	0.187			37.1	(345)	37.1	(412)
	2	0.004	0.003	0.157	0.175			31.9	(357)	43.2	(410)

(a) Percent of those organisms alive classified as healthy; number in parentheses is N of sample.
(b) Unit 1 down, circulating pumps on.

APPENDIX C

MICROZOOPLANKTON VIABILITY DATA
BOWLINE POINT PLANT 1975, 1976

TABLE C-1 MICROZOOPLANKTON INITIAL (0-HOUR) SURVIVAL DATA AT THE BOWLINE POINT PLANT, 1976

		Temperature (C)		Percentage Survival[a]			
Species	Date	Intake	Discharge	Intake	(n_1)	Discharge	(n_2)
Total micro-zooplankton	8 MAR	3.2	12.4	53.4	(88)	54.0	(74)
	22 MAR	5.0	14.4	33.6	(520)	45.6	(171)
	5 APR	7.8	16.8	34.7	(92)	57.1	(42)
	26 APR	10.6	19.7	43.7	(990)	60.2	(680)
	10 MAY	15.8	25.2	70.9	(1,655)	38.9	(488)*
	24 MAY	16.5	23.9	69.8	(3,260)	45.8	(1,559)*
	7 JUN	18.7	27.6	60.9	(1,866)	38.3	(1,074)*
	21 JUN	24.5	33.0	60.0	(3,352)	56.6	(2,951)*
	12 JUL	25.1	29.1	75.7	(713)	79.0	(624)
	27 JUL	24.0	32.6	93.2	(1,323)	94.4	(3,507)
	9 AUG	25.0	32.0	88.0	(327)	80.4	(1,294)*
	23 AUG	26.0	35.0	96.6	(4,776)	87.0	(1,686)*
	13 SEP	23.5	33.0	92.3	(2,247)	89.0	(1,416)*
	27 SEP	21.0	29.0	96.9	(1,121)	93.0	(790)*
	4 OCT	18.9	28.3	96.6	(148)	91.5	(238)*
	25 OCT	12.8	24.8	70.5	(560)	60.9	(1,097)*
	1 NOV	10.0	21.6	59.7	(880)	49.0	(724)*
	15 NOV	7.2	19.9	63.1	(328)	58.2	(199)
	6 DEC	3.7	16.2	84.7	(1,060)	84.4	(954)
Copepod nauplii	22 MAR	5.0	14.4	32.5	(455)	43.0	(144)
	5 APR	7.8	16.8	22.2	(36)	57.1	(35)
	26 APR	10.6	19.7	43.1	(878)	60.7	(606)
	10 MAY	15.8	25.2	49.5	(452)	15.2	(230)*
	24 MAY	16.5	23.9	56.1	(837)	31.9	(244)*
	7 JUN	18.7	27.6	68.6	(1,118)	34.7	(492)*
	21 JUN	24.5	33.0	52.1	(1,078)	42.2	(873)*
	12 JUL	25.1	29.1	68.7	(326)	74.9	(271)
	27 JUL	24.0	32.6	92.3	(757)	94.5	(3,003)
	9 AUG	25.0	32.0	83.7	(129)	79.5	(1,101)
	23 AUG	26.0	35.0	97.2	(4,197)	88.5	(1,419)*
	13 SEP	23.5	33.0	93.2	(2,029)	91.1	(1,303)*
	27 SEP	21.0	29.0	97.2	(993)	93.3	(661)*
	4 OCT	18.9	28.3	96.4	(114)	91.2	(194)
	25 OCT	12.8	24.8	54.0	(50)	65.0	(423)
	1 NOV	10.0	21.6	63.2	(106)	59.7	(144)
	6 DEC	3.7	16.2	87.2	(836)	84.5	(692)

(a) n_1 and n_2 represent intake and discharge sample sizes, respectively.

Note: * indicates survival at the discharge significantly lower than that at the intake at the $\alpha = 0.05$ level for a one-tailed t-test.

TABLE C-1 (CONT.)

		Temperature (C)		Percentage Survival$^{(a)}$			
Species	Date	Intake	Discharge	Intake	(n_1)	Discharge	(n_2)
Eurytemora affinis	7 JUN	18.7	27.6	72.5	(51)	41.2	(80)*
	12 JUL	25.1	29.1	82.9	(41)	80.9	(21)
	27 JUL	24.0	32.6	97.2	(36)	96.6	(30)
	6 DEC	3.7	16.2	100.0	(43)	86.6	(30)*
Acartia tonsa	27 JUL	24.0	32.6	94.9	(158)	91.9	(62)
	23 AUG	26.0	35.0	90.6	(64)	71.4	(21)*
	27 SEP	21.0	29.0	96.7	(61)	86.0	(50)*
Halicyclops fosteri	10 MAY	15.8	25.2	94.0	(50)	82.0	(39)
	7 JUN	18.7	27.6	88.0	(25)	75.5	(45)
	21 JUN	24.5	33.0	88.5	(87)	83.4	(121)
	25 OCT	12.8	24.8	96.6	(89)	91.3	(23)
	1 NOV	10.0	21.6	92.5	(67)	83.7	(43)
Bosmina longirostris	7 JUN	18.7	27.6	91.5	(59)	93.1	(44)
	21 JUN	24.5	33.0	85.8	(78)	75.9	(54)
	12 JUL	25.1	29.1	84.3	(32)	88.0	(50)
	25 OCT	12.8	24.8	97.1	(70)	75.0	(28)*
	6 DEC	3.7	16.2	81.8	(77)	91.9	(124)
Keratella cochlearis	10 MAY	15.8	25.2	85.9	(228)	56.9	(65)*
	24 MAY	16.5	23.9	78.7	(1,183)	64.9	(377)*
	7 JUN	18.7	27.6	22.1	(307)	24.7	(251)
	21 JUN	24.5	33.0	35.4	(708)	60.9	(801)
	25 OCT	12.8	24.8	50.6	(221)	49.6	(475)
	1 NOV	10.0	21.6	45.7	(485)	32.5	(375)*
	15 NOV	7.2	19.9	64.2	(95)	64.5	(62)
	6 DEC	3.7	16.2	26.1	(42)	58.8	(34)
Notholca accuminata	8 MAR	3.2	12.4	57.6	(26)	45.0	(20)
	24 MAY	16.5	23.9	73.2	(325)	28.2	(418)*
	21 JUN	24.5	33.0	77.1	(752)	58.1	(564)*
	1 NOV	10.0	21.6	75.7	(66)	65.7	(35)
	15 NOV	7.2	19.9	50.0	(90)	40.6	(59)

(a) n_1 and n_2 represent intake and discharge sample sizes, respectively.

Note: * indicates survival at the discharge significantly lower than that at the intake at the $\alpha = 0.05$ level for a one-tailed t-test.

TABLE C-1 (CONT.)

Species	Date	Temperature (C)		Percentage Survival[(a)]			
		Intake	Discharge	Intake	(n_1)	Discharge	(n_2)
Kellicottia longispina	24 MAY	16.5	23.9	72.0	(43)	42.0	(50)*
	7 JUN	18.7	27.6	59.5	(42)	31.3	(51)*
	21 JUN	24.5	33.0	58.3	(36)	38.4	(26)
Brachionus calyciflorus	24 MAY	16.5	23.9	65.1	(43)	46.0	(50)
	21 JUN	24.5	33.0	76.8	(320)	64.0	(300)*
	1 NOV	10.0	21.6	64.7	(34)	52.6	(38)
Pelecypod veliger	27 JUL	24.0	32.6	97.1	(35)	98.3	(62)
	23 AUG	26.0	35.0	86.5	(52)	62.9	(54)*
Gastropod veliger	12 JUL	25.1	29.1	88.6	(167)	97.5	(120)
	27 JUL	24.0	32.6	93.7	(96)	93.0	(115)

(a) n_1 and n_2 represent intake and discharge sample sizes, respectively.

Note: * indicates survival at the discharge significantly lower than that at the intake at the $\alpha = 0.05$ level for a one-tailed t-test.

TABLE C-2 MICROZOOPLANKTON SURVIVAL DATA OBSERVED 48 HOURS AFTER ENTRAINMENT AT THE BOWLINE POINT PLANT, 1976

		Temperature (C)		Percentage Survival(a)			
Species	Date	Intake	Discharge	Intake	(n_1)	Discharge	(n_2)
Total micro-zooplankton	8 MAR	3.2	12.4	56.3	(55)	49.3	(83)
	22 MAR	5.0	14.4	51.7	(512)	59.4	(153)
	5 APR	7.8	16.8	66.2	(83)	61.1	(54)
	26 APR	10.6	19.7	55.2	(577)	45.3	(543)*
	10 MAY	15.8	25.2	63.3	(1,027)	52.2	(544)*
	24 MAY	16.5	23.9	76.7	(1,980)	48.1	(1,458)*
	7 JUN	18.7	27.6	26.4	(995)	17.7	(813)*
	21 JUN	24.5	33.0	52.7	(2,351)	59.4	(1,888)
	12 JUL	25.1	29.1	66.1	(411)	47.2	(292)*
	27 JUL	24.0	32.6	74.6	(512)	86.0	(1,676)
	9 AUG	25.0	32.0	76.3	(220)	73.5	(526)
	23 AUG	26.0	35.0	77.3	(2,562)	75.8	(1,103)
	13 SEP	23.5	33.0	76.2	(1,251)	84.4	(785)
	27 SEP	21.0	29.0	75.4	(465)	83.5	(455)
	4 OCT	18.9	28.3	94.4	(181)	87.0	(131)*
	25 OCT	12.8	24.8	59.6	(528)	60.2	(970)
	1 NOV	10.0	21.6	66.0	(777)	69.5	(614)
	15 NOV	7.2	19.9	64.8	(242)	64.0	(203)
	6 DEC	3.7	16.2	78.7	(330)	70.6	(286)*
Copepod nauplii	22 MAR	5.0	14.4	52.0	(459)	58.9	(129)
	5 APR	7.8	16.8	69.6	(33)	69.5	(23)
	26 APR	10.6	19.7	52.6	(469)	43.8	(474)*
	10 MAY	15.8	25.2	39.1	(240)	42.4	(231)
	24 MAY	16.5	23.9	62.3	(69)	34.7	(187)*
	7 JUN	18.7	27.6	17.7	(457)	19.1	(297)
	21 JUN	24.5	33.0	42.1	(472)	37.1	(218)
	12 JUL	25.1	29.1	53.9	(89)	42.3	(26)
	27 JUL	24.0	32.6	90.3	(83)	85.9	(1,142)
	9 AUG	25.0	32.0	90.4	(84)	68.9	(319)*
	23 AUG	26.0	35.0	77.6	(2,191)	78.9	(880)
	13 SEP	23.5	33.0	77.2	(1,137)	84.6	(703)
	27 SEP	21.0	29.0	82.0	(350)	85.1	(309)
	4 OCT	18.9	28.3	94.6	(149)	88.4	(104)
	25 OCT	12.8	24.8	45.1	(31)	55.4	(361)
	1 NOV	10.0	21.6	50.0	(78)	46.8	(96)
	6 DEC	3.7	16.2	95.2	(169)	86.3	(66)*

(a) n_1 and n_2 represent intake and discharge sample sizes, respectively.

Note: * indicates survival at the discharge significantly lower than that at the intake at the $\alpha = 0.05$ level for a one-tailed t-test.

TABLE C-2 (CONT.)

		Temperature (C)		Percentage Survival$^{(a)}$			
Species	Date	Intake	Discharge	Intake	(n_1)	Discharge	(n_2)
Eurytemora affinis	7 JUN	18.7	27.6	17.2	(29)	20.3	(59)
	27 JUL	24.0	32.6	93.7	(48)	96.0	(25)
	6 DEC	3.7	16.2	93.3	(45)	90.9	(55)
Acartia tonsa	27 JUL	24.0	32.6	51.3	(74)	79.6	(103)
	23 AUG	26.0	35.0	68.9	(87)	50.0	(40)*
	27 SEP	21.0	29.0	20.9	(43)	52.1	(46)
Halicyclops fosteri	10 MAY	15.8	25.2	85.0	(67)	100.0	(27)
	7 JUN	18.7	27.6	66.6	(30)	52.7	(36)
	21 JUN	24.5	33.0	87.6	(73)	73.1	(97)*
	1 NOV	10.0	21.6	88.4	(52)	85.7	(42)
Bosmina longirostris	7 JUN	18.7	27.6	90.7	(65)	66.6	(60)*
	21 JUN	24.5	33.0	48.0	(100)	65.7	(108)
	12 JUL	25.1	29.1	68.9	(58)	65.2	(46)
	25 OCT	12.8	24.8	88.1	(76)	58.3	(24)*
	6 DEC	3.7	16.2	39.1	(23)	61.5	(65)
Keratella cochlearis	10 MAY	15.8	25.2	94.3	(212)	76.9	(78)*
	24 MAY	16.5	23.9	86.3	(971)	74.8	(409)*
	7 JUN	18.7	27.6	16.8	(267)	10.1	(177)*
	21 JUN	24.5	33.0	60.0	(681)	60.7	(675)
	25 OCT	12.8	24.8	43.8	(210)	67.9	(440)
	1 NOV	10.0	21.6	68.3	(468)	80.7	(338)
	15 NOV	7.2	19.9	69.1	(81)	68.1	(44)
	6 DEC	3.7	16.2	0.0	(32)	15.6	(32)
Notholca accuminata	24 MAY	16.5	23.9	67.6	(523)	34.4	(429)*
	21 JUN	24.5	33.0	48.6	(646)	56.5	(502)
	1 NOV	10.0	21.6	67.2	(61)	59.3	(32)
	15 NOV	7.2	19.9	65.7	(73)	62.0	(58)

(a) n_1 and n_2 represent intake and discharge sample sizes, respectively.

Note: * indicates survival at the discharge significantly lower than that at the intake at the $\alpha = 0.05$ level for a one-tailed t-test.

TABLE C-2 (CONT.)

Species	Date	Temperature (C)		Percentage Survival[a]			
		Intake	Discharge	Intake	(n_1)	Discharge	(n_2)
Kellicottia longispina	24 MAY	16.5	23.9	90.3	(52)	24.1	(58)*
	7 JUN	18.7	27.6	8.8	(34)	0.0	(46)
	21 JUN	24.5	33.0	68.9	(29)	65.0	(20)
Brachionus calyciflorus	24 MAY	16.5	23.9	55.1	(49)	30.5	(59)*
	21 JUN	24.5	33.0	20.1	(174)	50.0	(132)
	1 NOV	10.0	21.6	48.7	(39)	32.5	(43)
Pelecypod veliger	27 JUL	24.0	32.6	33.3	(30)	57.7	(45)
	23 AUG	26.0	35.0	11.5	(26)	33.3	(39)
Gastropod veliger	12 JUL	25.1	29.1	74.1	(147)	25.5	(137)*
	27 JUL	24.0	32.6	76.9	(130)	91.7	(158)

(a) n_1 and n_2 represent intake and discharge sample sizes, respectively.

Note: * indicates survival at the discharge significantly lower than that at the intake at the $\alpha = 0.05$ level for a one-tailed t-test.

TABLE C-3 MICROZOOPLANKTON INITIAL (0-HOUR) SURVIVAL DATA AT THE BOWLINE POINT PLANT, 1975

Date	Temperature (C)		Percentage Survival[a]	
	Intake	Discharge	Intake (n_1)	Discharge (n_2)
		Total microzooplankton		
29 JUL - 5 AUG	26.0-28.0	35.0-37.0	76.3 (9,190)	56.8 (8,264)*
29 SEP - 1 OCT	20.0-20.0	27.5-29.0	63.2 (625)	63.7 (699)
16 DEC - 17 DEC	5.5-6.0	11.0-11.0	72.9 (1,330)	54.3 (792)*
		Copepod nauplii		
29 JUL - 5 AUG	26.0-28.0	35.0-37.0	77.2 (7,764)	55.2 (7,093)*
29 SEP - 1 OCT	20.0-20.0	27.5-29.0	40.4 (156)	27.9 (136)*
16 DEC - 17 DEC	5.5-6.0	11.0-11.0	73.4 (791)	50.3 (529)*
		Eurytemora affinis		
29 JUL - 5 AUG	26.0-28.0	35.0-37.0	92.0 (472)	51.4 (107)*
16 DEC - 17 DEC	5.5-6.0	11.0-11.0	82.9 (82)	40.9 (22)*
		Acartia tonsa		
29 JUL - 5 AUG	26.0-28.0	35.0-27.0	75.9 (29)	33.0 (91)*
		Halicyclops fosteri		
29 JUL - 5 AUG	26.0-28.0	35.0-37.0	83.2 (113)	64.2 (67)*
29 SEP - 1 OCT	20.0-20.0	27.5-29.0	79.5 (327)	81.4 (312)
		Bosmina longirostris		
29 JUL - 5 AUG	21.0-28.0	35.0-37.0	85.7 (35)	50.8 (65)*
29 SEP - 1 OCT	20.0-20.0	27.5-29.0	73.5 (49)	85.5 (69)

(a) n_1 and n_2 represent intake and discharge sample sizes, respectively.

Note: * indicates survival at the discharge significantly lower than that at the intake at the $\alpha = 0.05$ level for a one-tailed t-test.

TABLE C-3 (CONT.)

Date	Temperature (C)		Percentage Survival[a]			
	Intake	Discharge	Intake (n_1)		Discharge (n_2)	
Keratella cochlearis						
29 SEP - 1 OCT	20.0-20.0	27.5-29.0	32.1	(28)	46.8	(77)
16 DEC - 17 DEC	5.5-6.0	11.0-11.0	53.7	(41)	62.9	(35)
Notholca accuminata						
10 DEC - 12 DEC	5.5-6.0	11.0-11.0	71.9	(377)	65.3	(150)
Gastropod veliger						
29 JUL - 5 AUG	26.0-26.0	35.0-37.0	85.8	(162)	63.3	(251)*

(a) n_1 and n_2 represent intake and discharge sample sizes, respectively.

Note: * indicates survival at the discharge significantly lower than that at the intake at the $\alpha = 0.05$ level for a one-tailed t-test.

TABLE C-4 MICROZOOPLANKTON SURVIVAL DATA OBSERVED 48 HOURS AFTER ENTRAINMENT AT THE BOWLINE POINT PLANT, 1975

	Temperature (C)		Percentage Survival$^{(a)}$			
Date	Intake	Discharge	Intake (n_1)		Discharge (n_2)	
Total microzooplankton						
29 JUL - 5 AUG	26.0-28.0	35.0-37.0	65.0	(2,628)	31.3	(2,166)*
29 SEP - 1 OCT	20.0-20.0	27.5-29.0	46.5	(561)	65.3	(504)
16 DEC - 17 DEC	5.5-6.0	11.0-11.0	53.1	(729)	33.6	(578)*
Copepod nauplii						
29 JUL - 5 AUG	26.0-28.0	35.0-37.0	57.9	(1,672)	25.5	(1,701)*
16 DEC - 17 DEC	5.5-6.0	11.0-11.0	69.4	(337)	32.8	(409)*
Eurytemora affinis						
16 DEC - 17 DEC	5.5-6.0	11.0-11.0	82.8	(87)	40.0	(25)*
Acartia tonsa						
29 JUL - 5 AUG	26.0-28.0	35.0-27.0	59.7	(67)	34.8	(46)*
Halicyclops fosteri						
29 SEP - 1 OCT	20.0-20.0	27.5-29.0	52.4	(313)	73.9	(272)
Bosmina longirostris						
29 JUL - 5 AUG	26.0-28.0	35.0-37.0	72.7	(33)	31.0	(29)*
29 SEP - 1 OCT	20.0-20.0	27.5-29.0	63.0	(73)	66.7	(81)

(a) n_1 and n_2 represent intake and discharge sample sizes, respectively.

Note: * indicates survival at the discharge significantly lower than that at the intake at the $\alpha = 0.05$ level for a one-tailed t-test.

TABLE C-4 (CONT.)

Date	Temperature (C)		Percentage Survival[a]			
	Intake	Discharge	Intake (n_1)		Discharge (n_2)	
Keratella cochlearis						
29 SEP - 1 OCT	20.0-20.0	27.5-29.0	28.9	(38)	57.3	(75)
16 DEC - 17 DEC	5.5-6.0	11.0-11.0	19.0	(21)	26.7	(30)
Notholca accuminata						
16 DEC - 17 DEC	5.5-6.0	11.0-11.0	16.6	(235)	33.3	(78)
Gastropod veliger						
29 JUL - 5 AUG	26.0-28.0	35.0-37.0	64.1	(92)	55.7	(140)

(a) n_1 and n_2 represent intake and discharge sample sizes, respectively.

Note: * indicates survival at the discharge significantly lower than that at the intake at the $\alpha = 0.05$ level for a one-tailed t-test.

APPENDIX D

ENTRAINMENT SURVIVAL DATA FOR MACROZOOPLANKTON COLLECTED AT THE BOWLINE POINT PLANT DURING 1975, 1976, AND 1978

TABLE D-1 INITIAL AND EXTENDED SURVIVAL OF GAMMARUS AT THE BOWLINE POINT PLANT, HUDSON RIVER ESTUARY, 1975

Date	Station	Mean Temp.	Temp. Range	DO (mg/ℓ)	Cond. (μMHOS)	pH	Salinity (ppt)	Number Samples	Number Collected	Initial Proportion Surviving	Entrainment Survival, S_e*	Latent Effects Subsample	Extended Survival						
													Initial	6	12	24	48	72	96
29 JUL	I	27.0	--	--	--	--	--	1	8	0.500		4	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	D	35.0	--	--	--	--	--	1	7	0.857	--	1	1.000	1.000	1.000	1.000	1.000	0.000	0.000
30 JUL	I	27.0	--	--	--	--	--	1	15	1.000		15	1.000	0.400	0.400	0.400	0.400	0.400	0.400
	D	37.0	--	--	--	--	--	1	21	0.714	71.4	8	1.000	1.000	0.875	0.875	0.875	0.875	0.875
31 JUL	I	28.0	--	--	--	--	--	1	3	1.000		2	1.000	0.500	0.500	0.500	0.500	0.500	0.500
	D	36.0	--	--	--	--	--	1	30	0.867	--	21	1.000	0.667	0.667	0.524	0.381	0.288	0.190
4 AUG	I	28.0	--	--	--	--	--	1	12	0.583		5	1.000	1.000	0.800	0.800	0.800	0.800	0.600
	D	36.0	--	--	--	--	--	1	6	0.833	100.0	5	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5 AUG	I	28.5	--	--	--	--	--	1	81	0.667		34	1.000	1.000	0.853	0.824	0.735	0.735	0.588
	D	36.0	--	--	--	--	--	1	26	0.846	--	16	1.000	0.000	0.000	0.000	0.000	0.000	0.000
29 SEP	I	20.0	--	--	--	--	--	1	38	0.947		14	1.000	0.857	0.857	0.857	0.786	0.786	0.786
	D	28.5	--	--	--	--	--	1	16	1.000	100.0	9	1.000	1.000	1.000	1.000	1.000	1.000	1.000
30 SEP	I	19.8	19.5-20.0	--	--	--	--	2	51	0.961		37	1.000	1.000	1.000	1.000	1.000	0.946	0.919
	D	26.0	23.5-28.5	--	--	--	--	2	28	0.893	92.9	11	1.000	0.727	0.636	0.636	0.636	0.636	0.364
1 OCT	I	20.0	--	--	--	--	--	1	57	1.000		23	1.000	0.913	0.913	0.870	0.826	0.783	0.739
	D	27.5	--	--	--	--	--	1	29	0.966	96.6	12	1.000	1.000	1.000	1.000	0.917	0.917	0.833
16 DEC	I	5.7	5.4- 6.0	11.6	2,210	7.7	1.1	2	102	0.804		35	1.000	1.000	0.971	0.971	0.971	0.971	0.943
	D	11.4	11.3-11.4	11.8	2,485	7.5	1.3	2	25	0.920	100.0	17	1.000	1.000	1.000	1.000	1.000	1.000	0.941
Total	I	--	--	--	--	--	--	11	367	0.837		169	1.000	0.917	0.876	0.864	0.834	0.817	0.763
	D	--	--	--	--	--	--	11	188	0.883	105.5	100	1.000	0.740	0.720	0.690	0.650	0.620	0.550

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

TABLE D-2 INITIAL AND EXTENDED SURVIVAL OF GAMMARUS AT THE BOWLINE POINT PLANT, HUDSON RIVER ESTUARY, 1976

Date	Station	Mean Temp.	Temp. Range	DO (mg/ℓ)	Cond. (µMHOS)	pH	Salinity (ppt)	Number Samples	Number Collected	Initial Prop. Surviving	Entrain. Survival, S_e*	Latent Effects Subsample	Extended Survival				
													Initial	24	48	72	96
8 MAR	I	3.2	--	13.4	11	7.7	--	1	36	0.972		30	1.000	0.933	0.933	0.933	0.900
	D	11.0	--	12.3	129	7.4	--	1	34	1.000	100.0	28	1.000	1.000	1.000	1.000	1.000
23 MAR	I	5.3	--	12.7	250	7.8	--	1	2	1.000		2	1.000	1.000	0.500	0.500	0.500
	D	14.1	--	11.3	290	7.9	--	1	9	0.778	--	2	1.000	1.000	1.000	1.000	1.000
5 APR	I	7.8	--	10.9	120	7.9	--	1	33	1.000		19	1.000	0.895	0.895	0.895	0.895
	D	16.8	--	9.7	160	7.9	--	1	15	0.933	93.3	5	1.000	0.600	0.600	0.600	0.600
26 APR	I	10.6	--	9.8	58	7.9	--	1	12	1.000		10	1.000	0.900	0.900	0.900	0.800
	D	19.5	--	9.3	67	7.8	--	1	27	0.926	92.6	21	1.000	0.905	0.905	0.810	0.762
10 MAY	I	15.8	--	9.5	130	7.5	--	1	130	0.977		44	1.000	0.932	0.886	0.864	0.841
	D	25.2	--	9.0	170	7.9	--	1	166	0.922	94.4	20	1.000	0.900	0.700	0.550	0.450
24 MAY	I	16.5	--	9.6	130	7.2	--	1	103	0.903		20	1.000	0.900	0.500	0.150	0.150
	D	23.5	--	--	--	--	--	1	199	0.960	100.0	35	1.000	0.971	0.657	0.457	0.371
7 JUN	I	18.1	--	9.7	160	--	--	1	5	1.000		5	1.000	1.000	1.000	1.000	0.600
	D	23.5	--	--	--	--	--	1	11	0.909	--	4	1.000	1.000	1.000	1.000	1.000
21 JUN	I	23.9	22.8-25.0	--	165	--	--	2	221	0.977		65	1.000	0.943	0.846	0.769	0.662
	D	30.0	28.0-32.0	--	--	--	--	2	82	0.841	86.1	34	1.000	0.912	0.765	0.706	0.559
12-13 JUL	I	25.6	25.1-26.0	7.5	250	7.9	--	2	262	0.992		27	1.000	1.000	0.889	0.889	0.852
	D	30.2	30.0-30.3	--	--	--	--	2	208	0.947	95.5	18	1.000	1.000	1.000	1.000	1.000
26 JUL	I	24.5	--	5.8	792	--	--	1	446	0.991		33	1.000	0.939	0.909	0.909	0.909
	D	34.0	--	--	--	--	--	1	106	0.962	97.1	28	1.000	1.000	0.964	0.964	0.964
9 AUG	I	25.0	--	--	2,700	--	2.0	1	715	0.990		34	1.000	1.000	0.941	0.853	0.853
	D	32.0	--	--	2,450	--	2.0	1	99	0.949	95.9	20	1.000	1.000	0.800	0.800	0.650
23 AUG	I	26.0	--	8.2	4,030	--	3.0	1	330	0.988		28	1.000	1.000	0.964	0.964	0.964
	D	35.0	--	9.2	4,030	--	3.0	1	114	0.991	100.0	21	1.000	0.905	0.762	0.714	0.714
13 SEP	I	23.5	--	7.3	2,020	7.5	--	1	6	0.667		0	--	--	--	--	--
	D	33.0	--	--	2,010	7.3	--	1	4	0.250	--	1	1.000	1.000	1.000	1.000	1.000
27 SEP	I	21.0	--	--	--	--	--	1	5	0.800		2	1.000	1.000	1.000	1.000	1.000
	D	29.0	--	--	--	7.8	--	1	16	1.000	--	6	1.000	1.000	1.000	1.000	1.000
4 OCT	I	18.9	--	7.9	335	7.4	--	1	10	1.000		2	1.000	1.000	1.000	1.000	1.000
	D	28.3	--	7.6	405	6.7	--	1	5	1.000	--	1	1.000	1.000	1.000	1.000	1.000
25 OCT	I	12.8	--	9.3	250	--	--	1	7	1.000		3	1.000	1.000	1.000	1.000	1.000
	D	24.7	--	9.0	280	--	--	1	10	0.900	--	6	1.000	1.000	1.000	1.000	1.000

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

TABLE D-2 (CONT.)

Date	Station	Mean Temp.	Temp. Range	DO (mg/ℓ)	Cond. (μMHOS)	pH	Salinity (ppt)	Number Samples	Number Collected	Initial Prop. Surviving	Entrain. Survival, S_e*	Latent Effects Subsample	Extended Survival				
													Initial	24	48	72	96
1 NOV	I	10.0	--	9.9	160	--	--	1	22	0.773		16	1.000	0.938	0.938	0.813	0.688
	D	20.9	--	9.6	200	--	--	1	68	0.956	100.0	27	1.000	1.000	1.000	0.926	0.815
15 NOV	I	7.1	--	10.2	150	7.9	--	1	143	0.951		61	1.000	0.967	0.918	0.820	0.721
	D	19.6	--	9.9	200	7.8	--	1	131	0.893	93.9	40	1.000	0.900	0.850	0.775	0.475
6 DEC	I	3.6	--	10.9	970	7.9	--	1	22	0.909		16	1.000	1.000	1.000	0.929	0.929
	D	16.1	--	10.5	1,250	7.9	--	1	36	0.833	91.6	21	1.000	1.000	1.000	1.000	1.000
Total	I	--	--	--	--	--	--	1	2,510	0.979		417	1.000	0.964	0.890	0.830	0.779
	D	--	--	--	--	--	--	1	1,340	0.933	95.3	338	1.000	0.953	0.864	0.805	0.719

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

TABLE D-3 INITIAL AND EXTENDED SURVIVAL OF GAMMARUS AT THE BOWLINE POINT PLANT, HUDSON RIVER ESTUARY, 1978

													Extended Survival							
Date	Station	Mean Temp.	Temp. Range	DO (mg/ℓ)	Cond. (µMHOS)	pH	Salinity (ppt)	Number Samples	Number Collected	Initial Proportion Surviving	Entrainment Survival, S_e*	Latent Effects Subsample	Initial	3	6	12	24	48	72	96
20 MAR	I	2.9	2.0- 4.0	11.6	770	8.1	0.7	4	598	0.968		168	1.000	0.994	0.976	0.970	0.958	0.958	0.958	0.952
	D	10.0	8.0-12.0	--	--	--	--	4	248	0.919	94.9	152	1.000	1.000	1.000	0.980	0.980	0.980	0.980	0.967
10 APR	I	6.3	6.0- 7.0	10.7	110	8.1	0.1	4	1,319	0.978		184	1.000	0.967	0.951	0.935	0.924	0.924	0.918	0.918
	D	15.8	15.0-16.0	--	--	--	--	4	373	0.911	93.1	177	1.000	0.943	0.921	0.910	0.904	0.904	0.898	0.898
22 MAY	I	15.8	15.5-16.0	10.0	186	7.6	0.1	4	1,297	0.970		119	1.000	0.992	0.983	0.958	0.933	0.773	0.706	0.487
	D	23.5	20.0-26.0	--	--	--	--	4	1,339	0.979	100.0	59	1.000	0.983	0.983	0.983	0.983	0.847	0.712	0.542
12 JUN	I	21.7	21.3-22.0	10.6	171	7.4	0.1	4	552	0.911		48	1.000	0.958	0.958	0.958	0.792	0.771	0.729	0.729
	D	27.3	26.0-29.0	--	--	--	--	4	307	0.928	100.0	27	1.000	0.889	0.815	0.778	0.667	0.630	0.518	0.518
26 JUN	I	23.1	23.0-23.5	9.3	2,680	7.4	1.4	4	242	0.926		41	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	D	30.8	29.0-32.0	--	--	--	--	4	134	0.918	99.1	50	1.000	1.000	0.960	0.960	0.940	0.940	0.860	0.800
5 JUL	I	21.8	21.6-22.0	8.7	8,260	7.4	4.9	4	296	0.919		96	1.000	1.000	1.000	1.000	0.990	0.990	0.979	0.969
	D	26.8	26.0-27.0	--	--	--	--	4	203	0.872	94.9	28	1.000	1.000	1.000	0.929	0.929	0.929	0.929	0.929
18 JUL	I	24.3	23.8-24.8	3.9	13,820	8.0	0.7	4	476	0.994		128	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	D	33.5	32.0-35.0	--	--	--	--	4	430	0.967	97.5	73	1.000	0.986	0.986	0.986	0.918	0.918	0.918	0.918
14 AUG	I	26.8	26.5-27.0	--	6,250	6.9	3.4	2	821	0.950		199	1.000	1.000	1.000	1.000	0.995	0.990	0.950	0.935
	D	36.0	36.0	--	--	--	--	2	204	0.784	82.5	49	1.000	0.918	0.878	0.878	0.878	0.878	0.857	0.796
28 AUG	I	26.1	25.7-27.0	7.7	7,820	7.6	4.3	4	694	0.833		242	1.000	1.000	0.996	0.996	0.988	0.979	0.946	0.930
	D	34.8	33.0-36.0	--	--	--	--	4	497	0.980	100.0	28	1.000	1.000	1.000	1.000	0.929	0.929	0.929	0.929
11 SEP	I	24.2	23.8-25.0	7.5	10,815	7.4	6.1	4	400	0.915		210	1.000	0.986	0.976	0.967	0.967	0.933	0.929	0.905
	D	32.0	30.0-34.0	--	--	--	--	4	144	0.986	100.0	17	1.000	1.000	1.000	1.000	0.882	0.588	0.529	0.529
25 SEP	I	21.9	21.6-22.0	7.5	6,775	7.6	4.0	4	415	0.969		172	1.000	1.000	1.000	1.000	0.994	0.930	0.919	0.907
	D	29.0	28.0-30.0	--	--	--	--	4	156	0.961	99.2	15	1.000	1.000	1.000	1.000	1.000	0.933	0.800	0.800
16 OCT	I	17.3	16.3-18.0	8.7	7,530	7.3	5.1	4	582	0.928		67	1.000	1.000	1.000	0.970	0.955	0.940	0.940	0.940
	D	26.5	26.0-27.0	--	--	--	--	4	528	0.985	100.0	35	1.000	1.000	1.000	1.000	0.943	0.914	0.743	0.571
Total	I	--	--	--	--	--	--	46	7,692	0.944		1,674	1.000	0.992	0.987	0.980	0.969	0.943	0.926	0.901
	D	--	--	--	--	--	--	46	4,563	0.951	100.7	708	1.000	0.973	0.959	0.946	0.924	0.901	0.864	0.832

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

TABLE D-4 NUMBER OF ALIVE AND DEAD *GAMMARUS* COLLECTED AT THE INTAKE AND DISCHARGE SAMPLING STATIONS OF THE BOWLINE POINT PLANT, 1975, 1976, AND 1978

		1975		1976		1978	
		Initial	24-Hr.	Initial	24-Hr.	Initial	24-Hr.
Gammarus daiberi							
Intake	A	285	137	2,435	391	X	
	D	54	13	53	14	X	
Discharge	A	135	56	1,244	320	X	
	D	21	13	89	16	X	
Gammarus tigrinus							
Intake	A	7	4	17	7	X	
	D	3	0	0	0	X	
Discharge	A	4	4	4	0	X	
	D	0	0	1	0	X	
Gammarus fasciatus							
Intake	A	1	1	X		X	
	D	1	0	X		X	
Discharge	A	0	0	X		X	
	D	1	0	X		X	
Gammarus spp.							
Intake	A	14	4	5	4	7,265	1,623
	D	2	10	0	1	427	51
Discharge	A	27	12	2	2	4,339	654
	D	0	15	0	0	224	56
Total *Gammarus*							
Intake	A	307	145	2,457	402	7,265	1,623
	D	60	23	53	15	427	51
Discharge	A	166	72	1,250	322	4,339	654
	D	22	31	90	16	224	56

TABLE D-5 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG YEAR, STATION, AND INITIAL AND 24-HOUR SURVIVAL FOR *GAMMARUS* COLLECTED AT THE BOWLINE POINT PLANT, 1975, 1976, AND 1978

INITIAL

Source	df	G
Year x station independence	2	9.28*
Station x survival independence	1	1.34
Year x survival independence	2	89.78**
Year x station x survival interaction	2	51.78**
Year x station x survival independence	7	152.18**

24-HOUR

Source	df	G
Year x station independence	2	57.82**
Station x survival independence	1	34.20**
Year x survival independence	2	75.76**
Year x station x survival interaction	2	2.76
Year x station x survival independence	7	170.54**

Note:

df = degrees of freedom
G = test statistic
* denotes $p \leq 0.05$
** denotes $p \leq 0.001$

TABLE D-6 CORRELATION COEFFICIENTS OF INITIAL AND LATENT SURVIVAL VS. TEMPERATURE AND CONDUCTIVITY OF GAMMARUS COLLECTED AT THE BOWLINE POINT PLANT, 1975, 1976, AND 1978

	Temperature (C)						Conductivity			
	1975		1976		1978		1976		1978	
	r	n	r	n	r	n	r	n	r	n
Initial										
Intake	-0.234	9	0.255	19	-0.451	12	-0.309	19	-0.125	12
Discharge	-0.548	9	-0.138	19	-0.036	12	-0.185	13	-	NM
24-Hours										
Intake	-0.483	9	0.229	18	-0.246	12	0.415	17	0.577**	12
Discharge	-0.330	9	0.210	19	-0.193	12	0.133	13	-	NM

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r = correlation coefficient
n = sample size
** = significant at 0.05 level
NM = not measured

TABLE D-7 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG OBSERVATIONS, PUMP OPERATION MODE, AND SURVIVAL FOR *GAMMARUS* COLLECTED AT THE BOWLINE POINT PLANT, 1975, 1976, AND 1978

Source	df	G
Pump operation x survival independence	1	28.60**
Pump operation x observation independence	3	29.52**
Observation x survival independence	3	34.48**
Pump x survival x observation interaction	3	6.00
Pump x survival x observation independence	10	98.60**

Note:

df = degrees of freedom
G = test statistic
* denotes $p \leq 0.05$
** denotes $p \leq 0.001$

TABLE D-8 INITIAL AND LATENT SURVIVAL OF NEOMYSIS AMERICANA AT THE BOWLINE POINT PLANT, HUDSON RIVER ESTUARY, 1975

Date	Station	Mean Temp.	Temp. Range	DO (mg/ℓ)	Cond. (μMHOS)	pH	Salinity (ppt)	Number Samples	Number Collected	Initial Proportion Surviving	Entrainment Survival, S_e*	Latent Effects Subsample	Extended Survival Initial	6	12	24	48	72	96
29 JUL	I	27.0	--	--	--	--	--	1	1	0.000	--	--	--	--	--	--	--	--	--
30 JUL	I	27.0	--	--	--	--	--	1	1	1.000	--	0	--	--	--	--	--	--	--
31 JUL	I	28.0	--	--	--	--	--	1	2	0.000		--	--	--	--	--	--	--	--
	D	36.0	--	--	--	--	--	1	2	0.000	--	--	--	--	--	--	--	--	--
4 AUG	I	28.0	--	--	--	--	--	1	2	1.000		2	1.000	1.000	0.000	0.000	0.000	0.000	0.000
	D	36.0	--	--	--	--	--	1	2	0.000	--	--	--	--	--	--	--	--	--
5 AUG	I	28.5	--	--	--	--	--	1	17	0.176		3	1.000	1.000	0.667	0.667	0.667	0.333	0.333
	D	36.0	--	--	--	--	--	1	6	0.500	--	3	1.000	1.000	0.667	0.333	0.333	0.333	0.333
29 SEP	I	20.0	--	--	--	--	--	1	1	0.000	--	--	--	--	--	--	--	--	--
30 SEP	I	19.8	--	--	--	--	--	2	3	0.000	--	--	--	--	--	--	--	--	--
16 DEC	I	5.7	5.4- 6.0	11.6	2,210	7.7	1.1	2	19	0.368		7	1.000	0.714	0.714	0.714	0.714	0.571	0.571
	D	11.4	11.3-11.4	11.8	2,485	7.5	1.3	2	31	0.839	100.0	26	1.000	0.885	0.692	0.654	0.500	0.500	0.385
Total	I	--	--	--	--	--	--	10	46	0.283		12	1.000	0.833	0.583	0.583	0.583	0.500	0.500
	D	--	--	--	--	--	--	5	41	0.707	249.8	29	1.000	0.897	0.690	0.621	0.483	0.483	0.379

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

TABLE D-9 INITIAL AND LATENT SURVIVAL OF *NEOMYSIS AMERICANA* AT THE BOWLINE POINT PLANT, HUDSON RIVER ESTUARY, 1976

Date	Station	Mean Temp.	Temp. Range	DO (mg/ℓ)	Cond. (µMHOS)	pH	Salinity (ppt)	Number Samples	Number Collected	Initial Prop. Surviving	Entrain. Survival, S_e*	Latent Effects Subsample	Extended Survival				
													Initial	24	48	72	96
26 JUL	I	24.5	--	5.8	792	--	--	1	28	0.857		13	1.000	0.846	0.846	0.692	0.538
	D	34.0	--	--	--	--	--	1	33	0.394	46.0	8	1.000	0.375	0.125	0.125	0.125
9 AUG	I	25.0	--	--	2,700	--	2.0	1	40	0.725		21	1.000	0.571	0.476	0.333	0.238
	D	32.0	--	--	2,450	--	2.0	1	59	0.678	93.5	23	1.000	--	--	--	--
23 AUG	I	26.0	--	8.2	4,030	--	3.0	1	8	1.000		6	1.000	1.000	1.000	0.667	0.500
	D	35.0	--	9.2	4,030	--	3.0	1	6	0.333	--	0					
13 SEP	I	23.5	--	7.3	2,020	7.5	--	1	74	0.851		38	1.000	0.789	0.474	0.394	0.211
	D	33.0	--	--	2,010	7.3	--	1	55	0.673	79.1	15	1.000	0.733	0.533	0.467	0.267
27 SEP	I	21.0	--	--	--	--	--	1	37	0.919		23	1.000	0.870	0.609	0.609	0.609
	D	29.0	--	--	--	7.8	--	1	76	0.882	96.0	35	1.000	0.800	0.743	0.714	0.657
4 OCT	I	18.9	--	7.9	335	7.4	--	1	64	0.891		24	1.000	0.833	0.667	0.458	0.250
	D	28.3	--	7.6	405	6.7	--	1	102	0.833	93.5	36	1.000	0.917	0.778	0.639	0.556
25 OCT	I	12.8	--	9.3	250	--	--	1	4	0.500		1	1.000	0.000	0.000	0.000	0.000
6 DEC	I	3.6	--	10.9	970	7.9	--	1	31	0.839		26	1.000	0.808	0.769	0.692	0.692
	D	16.1	--	10.5	1,250	7.9	--	1	14	0.429	51.1	6	1.000	0.667	0.667	0.500	0.333
Total	I	--	--	--	--	--	--	1	286	0.850		152	1.000	0.796	0.625	0.513	0.401
	D	--	--	--	--	--	--	1	349	0.728	85.6	123	1.000	0.789	0.642	0.537	0.439

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

TABLE D-10 INITIAL AND LATENT SURVIVAL OF NEOMYSIS AMERICANA AT THE BOWLINE POINT PLANT, HUDSON RIVER ESTUARY, 1978

Date	Station	Mean Temp.	Temp. Range	DO (mg/l)	Cond. (µMHOS)	pH	Salinity (ppt)	Number Samples	Number Collected	Initial Proportion Surviving	Entrainment Survival, S_e*	Latent Effects Subsample	Extended Survival							
													Initial	3	6	12	24	48	72	96
20 MAR	I	3.3	2.6- 4.0	11.6	770	8.1	0.7	2	4	1.000	--	0								
26 JUN	I	23.1	23.0-23.5	9.3	2,680	7.4	1.4	4	641	0.675		70	1.000	1.000	0.986	0.943	0.929	0.900	0.657	0.629
	D	30.8	--	--	--	--	--	4	165	0.618	91.6	18	1.000	0.944	0.778	0.722	0.722	0.722	0.389	0.278
5 JUL	I	21.8	21.6-22.0	8.7	8,547	7.5	5.0	4	413	0.775		90	1.000	0.922	0.878	0.867	0.822	0.767	0.744	0.622
	D	26.7	26.0-27.0	--	--	--	--	3	72	0.667	86.1	36	1.000	1.000	0.972	0.972	0.917	0.917	0.917	0.833
18 JUL	I	24.3	23.8-24.8	3.9	13,820	8.0	0.7	4	774	0.908		95	1.000	0.968	0.947	0.937	0.884	0.747	0.716	0.716
	D	33.5	32.0-35.0	--	--	--	--	4	305	0.777	85.6	31	1.000	1.000	1.000	0.968	0.903	0.742	0.677	0.677
14 AUG	I	26.8	26.5-27.0	--	6,250	6.9	3.4	2	404	0.965		52	1.000	0.961	0.923	0.788	0.596	0.461	0.365	0.173
	D	36.0	--	--	--	--	--	2	59	0.288	29.8	0								
28 AUG	I	26.1	25.7-27.0	7.7	7,820	7.6	4.3	4	221	0.778		65	1.000	0.985	0.985	0.985	0.969	0.861	0.661	0.538
	D	35.3	34.0-36.0	--	--	--	--	3	46	0.456	58.6	8	1.000	1.000	1.000	0.750	0.625	0.625	0.625	0.625
11 SEP	I	24.2	23.8-25.0	7.5	10,848	7.4	6.1	4	304	0.855		127	1.000	0.984	0.961	0.921	0.913	0.842	0.701	0.551
	D	32.0	30.0-34.0	--	--	--	--	4	114	0.895	100.0	44	1.000	1.000	0.977	0.909	0.841	0.773	0.636	0.568
25 SEP	I	21.9	21.6-22.0	7.5	6,775	7.6	4.0	4	702	0.769		118	1.000	0.975	0.958	0.941	0.924	0.822	0.746	0.619
	D	29.0	28.0-30.0	--	--	--	--	4	230	0.839	100.0	88	1.000	0.932	0.875	0.818	0.761	0.511	0.420	0.204
16 OCT	I	17.3	16.3-18.0	8.7	7,530	7.3	5.1	4	1,702	0.910		76	1.000	0.960	0.960	0.934	0.934	0.921	0.868	0.776
	D	26.5	26.0-27.0	--	--	--	--	4	1,246	0.973	100.0	86	1.000	0.988	0.988	0.965	0.930	0.849	0.465	0.337
Total	I	--	--	--	--	--	--	32	5,165	0.846		693	1.000	0.970	0.949	0.919	0.885	0.804	0.701	0.597
	D	--	--	--	--	--	--	28	2,237	0.864	102.1	311	1.000	0.971	0.942	0.897	0.846	0.717	0.540	0.418

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

TABLE D-11 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG YEAR, STATION, AND INITIAL AND 24-HOUR SURVIVAL FOR NEOMYSIS AMERICANA COLLECTED AT THE BOWLINE POINT PLANT, 1975, 1976, AND 1978

INITIAL

Source	df	G
Year x station independence	2	156.70**
Station x survival independence	1	0.14
Year x survival independence	2	78.02**
Year x station x survival interaction	2	32.38**
Year x station x survival independence	7	267.24**

24-HOUR

Source	df	G
Year x station independence	2	40.00**
Station x survival independence	1	4.76*
Year x survival independence	2	46.98**
Year x station x survival interaction	2	-3.42
Year x station x survival independence	7	88.32**

Note:

df = degrees of freedom
G = test statistic
* denotes $p \leq 0.05$
** denotes $p \leq 0.001$

TABLE D-12 CORRELATION COEFFICIENTS OF INITIAL AND LATENT SURVIVAL VS. TEMPERATURE AND CONDUCTIVITY OF *NEOMYSIS AMERICANA* COLLECTED AT THE BOWLINE POINT PLANT, 1975, 1976, AND 1978

	Temperature (C)						Conductivity			
	1975		1976		1978		1976		1978	
	r	n	r	n	r	n	r	n	r	n
Initial										
Intake	0.149	8	0.356	8	-0.471	9	0.140	7	0.015	9
Discharge	-0.819	4	-0.009	7	-0.685**	8	-0.212	5	--	NM
24-Hours										
Intake	-0.534	3	0.318	7	-0.413	8	0.438	7	0.088	8
Discharge	-9.999**	2	-0.674	5	-0.585	7	-0.731	3	--	NM

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r = correlation coefficient
n = sample size
** = significant at 0.05 level
NM = not measured

TABLE D-13 INITIAL AND LATENT SURVIVAL OF *CHAOBORUS PUNCTIPENNIS* AT THE BOWLINE POINT PLANT, HUDSON RIVER ESTUARY, 1975

Date	Station	Mean Temp.	Temp. Range	DO (mg/ℓ)	Cond. (μMHOS)	pH	Sali-nity (ppt)	Number Samples	Number Collected	Initial Proportion Surviving	Entrainment Survival, S_e*	Latent Effects Subsample	Extended Survival						
													Initial	6	12	24	48	72	96
29 JUL	I	27.0	--	--	--	--	--	1	51	0.804		24	1.000	0.958	0.958	0.762	0.417	0.417	0.292
	D	35.0	--	--	--	--	--	1	14	0.643	80.0	3	1.000	1.000	1.000	1.000	0.667	0.667	0.333
30 JUL	I	27.0	--	--	--	--	--	1	319	0.944		90	1.000	1.000	0.978	0.878	0.644	0.522	0.467
	D	37.0	--	--	--	--	--	1	306	0.951	100.0	98	1.000	1.000	1.000	0.867	0.724	0.643	0.602
31 JUL	1	28.0	--	--	--	--	--	1	292	0.966		76	1.000	0.987	0.974	0.921	0.711	0.658	0.579
	D	36.0	--	--	--	--	--	1	102	0.863	89.3	40	1.000	0.975	0.950	0.900	0.800	0.800	0.800
4 AUG	I	28.0	--	--	--	--	--	1	59	0.915		40	1.000	1.000	1.000	1.000	0.925	0.825	0.725
	D	36.0	--	--	--	--	--	1	34	0.882	96.4	30	1.000	0.967	0.967	0.967	0.900	0.833	0.833
5 AUG	I	28.5	--	--	--	--	--	1	175	0.880		55	1.000	1.000	1.000	0.964	0.909	0.782	0.636
	D	36.0	--	--	--	--	--	1	93	0.925	100.0	28	1.000	1.000	0.929	0.857	0.786	0.607	0.107
29 SEP	I	20.0	--	--	--	--	--	1	2	0.000		0							
	D	28.5	--	--	--	--	--	1	1	1.000	--	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000
30 SEP	I	20.0	--	--	--	--	--	1	3	1.000		1	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	D	28.5	--	--	--	--	--	1	3	1.000	--	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1 OCT	I	20.0	--	--	--	--	--	1	4	1.000		4	1.000	0.250	0.250	0.000	0.000	0.000	0.000
	D	27.5	--	--	--	--	--	1	9	0.889	--	8	1.000	1.000	1.000	1.000	1.000	1.000	1.000
16 DEC	I	5.4	5.4	11.6	2,210	7.7	1.1	1	2	1.000		2	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	D	11.4	11.3-11.4	11.8	2,445	7.5	1.3	2	5	1.000	--	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Total	I	--	--	--	--	--	--	9	907	0.927		292	1.000	0.983	0.973	0.904	0.692	0.644	0.548
	D	--	--	--	--	--	--	10	567	0.919	99.1	214	1.000	0.991	0.977	0.897	0.790	0.724	0.631

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

TABLE D-14 INITIAL AND LATENT SURVIVAL OF *CHAOBORUS PUNCTIPENNIS* AT THE BOWLINE POINT PLANT, HUDSON RIVER ESTUARY, 1976

Date	Station	Mean Temp.	Temp. Range	DO (mg/ℓ)	Cond. (μMHOS)	pH	Salinity (ppt)	Number Samples	Number Collected	Initial Prop. Surviving	Entrain. Survival, S_e*	Latent Effects Subsample	Extended Survival Initial	24	48	72	96
5 APR	I	7.8	--	10.9	120	7.9	--	1	2	1.000		2	1.000	1.000	1.000	1.000	1.000
26 APR	I	10.6	--	9.8	58	7.9	--	1	6	1.000		6	1.000	1.000	1.000	1.000	1.000
	D	19.5	--	9.3	67	7.8	--	1	9	1.000	--	9	1.000	1.000	1.000	1.000	1.000
10 MAY	I	15.8	--	9.5	130	7.5	--	1	6	0.667		4	1.000	1.000	1.000	1.000	0.750
	D	25.2	--	9.0	170	7.9	--	1	52	0.962	--	49	1.000	1.000	1.000	1.000	1.000
24 MAY	I	16.5	--	9.6	130	7.2	--	1	18	1.000		16	1.000	1.000	0.938	0.875	0.875
	D	23.5	--	--	--	--	--	1	11	0.818	81.8	9	1.000	1.000	1.000	1.000	1.000
7 JUN	D	23.5	--	--	--	--	--	1	16	0.938	--	15	1.000	1.000	1.000	1.000	0.867
21 JUN	I	23.9	22.8-25.0	--	165	--	--	2	4	0.750		4	1.000	1.000	1.000	1.000	0.750
	D	30.0	28.0-32.0	--	--	--	--	2	6	0.833	--	6	1.000	1.000	0.250	0.250	0.250
12-13 JUL	I	25.6	25.1-26.0	7.5	250	7.9	--	2	288	0.983		37	1.000	0.946	0.919	0.730	0.405
	D	30.2	30.0-30.3	--	--	--	--	2	180	0.939	95.5	38	1.000	0.974	0.895	0.763	0.605
26 JUL	I	24.5	--	5.8	792	--	--	1	75	0.960		34	1.000	0.971	0.912	0.824	0.706
	D	34.0	--	--	--	--	--	1	102	0.961	100.0	43	1.000	1.000	0.977	0.884	0.884
9 AUG	I	25.0	--	--	2,700	--	2.0	1	87	0.943		30	1.000	0.967	0.900	0.700	0.467
	D	32.0	--	--	2,450	--	2.0	1	32	0.875	92.8	21	1.000	0.952	0.905	0.857	0.762
23 AUG	I	26.0	--	8.2	4,030	--	3.0	1	147	0.980		36	1.000	0.944	0.750	0.639	0.528
	D	35.0	--	9.2	4,030	--	3.0	1	33	0.909	92.8	26	1.000	1.000	0.885	0.692	0.500
13 SEP	I	23.5	--	7.3	2,020	7.5	--	1	17	1.000		17	1.000	1.000	1.000	1.000	1.000
	D	33.0	--	--	2,010	7.3	--	1	11	1.000	100.0	11	1.000	1.000	0.909	0.909	0.909
27 SEP	I	21.0	--	--	--	--	--	1	6	1.000		6	1.000	1.000	0.833	0.833	0.833
	D	29.0	--	--	--	7.8	--	1	4	1.000	--	3	1.000	1.000	1.000	0.667	0.333
4 OCT	I	18.9	--	7.9	335	7.4	--	1	3	1.000		3	1.000	1.000	1.000	1.000	1.000
	D	28.3	--	7.6	405	6.7	--	1	1	1.000	--	1	1.000	1.000	1.000	1.000	1.000
25 OCT	I	12.8	--	9.3	250	--	--	1	17	1.000	--	17	1.000	1.000	1.000	0.941	0.941
1 NOV	I	10.0	--	9.9	160	--	--	1	6	1.000		6	1.000	1.000	1.000	1.000	1.000
	D	20.9	--	9.6	200	--	--	1	4	1.000	--	4	1.000	1.000	1.000	0.750	0.750
15 NOV	I	7.1	--	10.2	150	7.9	--	1	2	1.000		2	1.000	1.000	1.000	1.000	1.000
Total	I	--	--	--	--	--	--	17	684	0.972		220	1.000	0.973	0.909	0.809	0.677
	D	--	--	--	--	--	--	15	461	0.939	96.6	235	1.000	0.979	0.940	0.868	0.791

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

TABLE D-15 INITIAL AND LATENT SURVIVAL OF *CHAOBORUS PUNCTIPENNIS* AT THE BOWLINE POINT PLANT, HUDSON RIVER ESTUARY, 1978

Date	Station	Mean Temp.	Temp. Range	DO (mg/ℓ)	Cond. (μMHOS)	pH	Salinity (ppt)	Number Samples	Number Collected	Initial Proportion Surviving	Entrainment Survival, Se*	Latent Effects Subsample	Extended Survival							
													Initial	3	6	12	24	48	72	96
10 APR	I	6.0	--	10.7	110	8.1	0.1	1	1	1.000	--	0								
22 MAY	I	15.8	15.5-16.0	10.1	186	7.0	0.1	4	22	0.682		15	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.600
	D	23.5	20.0-26.0	--	--	--	--	4	42	0.976	100.0	36	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.816
12 JUN	I	21.7	21.3-22.0	10.6	171	7.4	0.1	4	14	0.857		12	1.000	1.000	1.000	1.000	0.917	0.750	0.750	0.500
	D	27.3	26.0-29.0	--	--	--	--	4	13	0.846	98.6	11	1.000	1.000	1.000	1.000	0.909	0.909	0.545	0.273
26 JUN	I	23.2	23.0-23.5	9.3	2,680	7.4	1.4	3	23	1.000		22	1.000	1.000	1.000	1.000	0.909	0.909	0.727	0.590
	D	30.0	29.0-31.0	--	--	--	--	2	7	0.857	--	6	1.000	1.000	1.000	1.000	1.000	1.000	0.500	0.500
5 JUL	I	21.9	21.6-22.0	9.7	8,170	7.4	4.9	3	17	1.000		17	1.000	1.000	1.000	1.000	1.000	1.000	0.882	0.824
	D	26.0	--	--	--	--	--	1	1	1.000	--	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
18 JUL	I	24.3	23.8-24.8	3.7	1,382	7.9	0.7	2	3	1.000		3	1.000	1.000	1.000	1.000	1.000	0.667	0.667	0.667
	D	32.0	--	--	--	--	--	1	2	1.000	--	2	1.000	1.000	1.000	1.000	0.500	0.000	0.000	0.000
28 AUG	I	26.2	25.7-27.0	7.5	7,770	7.6	4.2	3	4	0.250	--	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Total	I	--	--	--	--	--	--	20	84	0.857		70	1.000	1.000	1.000	1.000	0.957	0.900	0.829	0.629
	D	--	--	--	--	--	--	12	65	0.938	109.5	58	1.000	1.000	1.000	1.000	0.966	0.948	0.828	0.655

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

TABLE D-16 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG YEAR, STATION, AND INITIAL AND 24-HOUR SURVIVAL FOR *CHAOBORUS PUNCTIPENNIS* COLLECTED AT THE BOWLINE POINT PLANT, 1975, 1976, AND 1978

INITIAL

Source	df	G
Year x station independence	2	2.00
Station x survival independence	1	2.00
Year x survival independence	2	18.70**
Year x station x survival interaction	2	8.42*
Year x station x survival independence	7	31.12**

24-HOUR

Source	df	G
Year x station independence	2	83.00**
Station x survival independence	1	1.86
Year x survival independence	2	32.36**
Year x station x survival interaction	2	-1.54
Year x station x survival independence	7	115.68**

Note:

df = degrees of freedom
G = test statistic
* denotes $p \leq 0.05$
** denotes $p \leq 0.001$

TABLE D-17 CORRELATION COEFFICIENTS OF INITIAL AND LATENT SURVIVAL VS. TEMPERATURE AND CONDUCTIVITY OF *CHAOBORUS PUNCTIPENNIS* COLLECTED AT THE BOWLINE POINT PLANT, 1975, 1976 AND 1978

	Temperature (C)						Conductivity			
	1975		1976		1978		1976		1978	
	r	n	r	n	r	n	r	n	r	n
Initial										
Intake	0.027	9	-0.280	15	-0.577	7	0.134	14	0.076	7
Discharge	-0.471	9	-0.160	13	-0.052	5	-0.715**	7	--	NM
24-Hours										
Intake	0.127	9	-0.568**	15	-0.038	6	-0.628**	14	0.544	6
Discharge	-0.592	9	-0.279	13	-0.735	5	-0.321	7	--	NM

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r = correlation coefficient
n = sample size
** = significant at 0.05 level
NM = not measured

TABLE D-18 INITIAL AND LATENT SURVIVAL OF MONOCULODES EDWARDSI AT THE BOWLINE POINT PLANT, HUDSON RIVER ESTUARY, 1975

Date	Station	Mean Temp.	Temp. Range	DO (mg/ℓ)	Cond. (μMHOS)	pH	Salinity (ppt)	Number Samples	Number Collected	Initial Proportion Surviving	Entrainment Survival, S_e*	Latent Effects Subsample	Extended Survival						
													Initial	6	12	24	48	72	96
29 JUL	I	27.0	--	--	--	--	--	1	2	0.000		0	--	--	--	--	--	--	--
	D	35.0	--	--	--	--	--	1	5	0.200	--	1	1.000	1.000	1.000	1.000	1.000	0.000	0.000
30 JUL	I	27.0	--	--	--	--	--	1	12	0.667		8	1.000	1.000	1.000	0.250	0.000	0.000	0.000
	D	37.0	--	--	--	--	--	1	8	0.875	--	0	--	--	--	--	--	--	--
31 JUL	I	28.0	--	--	--	--	--	1	37	0.919		9	1.000	0.889	0.889	0.778	0.778	0.778	0.444
	D	36.0	--	--	--	--	--	1	23	0.348	37.9	3	1.000	1.000	1.000	0.000	0.000	0.000	0.000
4 AUG	I	28.0	--	--	--	--	--	1	21	0.762		9	1.000	1.000	0.889	0.889	0.889	0.889	0.889
	D	36.0	--	--	--	--	--	1	29	0.931	100.0	16	1.000	1.000	1.000	0.938	0.938	0.813	0.813
5 AUG	I	28.5	--	--	--	--	--	1	103	0.485		14	1.000	1.000	1.000	0.929	0.857	0.733	0.571
	D	36.0	--	--	--	--	--	1	41	0.854	100.0	9	1.000	1.000	1.000	1.000	1.000	1.000	1.000
29 SEP	I	20.0	--	--	--	--	--	1	67	0.791		14	1.000	0.857	0.714	0.643	0.143	0.000	0.000
	D	28.5	--	--	--	--	--	1	27	0.556	70.3	13	1.000	0.923	0.538	0.538	0.462	0.231	0.077
30 SEP	I	19.8	19.5-20.0	--	--	--	--	2	63	0.746		35	1.000	0.600	0.543	0.457	0.400	0.343	0.314
	D	26.0	23.5-28.5	--	--	--	--	2	61	0.738	98.9	26	1.000	0.731	0.654	0.577	0.462	0.462	0.462
1 OCT	I	20.0	--	--	--	--	--	1	8	0.625		0	--	--	--	--	--	--	--
	D	27.5	--	--	--	--	--	1	33	0.455		10	1.000	0.600	0.600	0.500	0.400	0.400	0.200
16 DEC	I	5.7	5.4-6.0	11.6	2,210	7.7	1.1	1	23	1.000		4	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	D	11.4	11.3-11.4	11.7	2,485	7.5	1.3	1	49	0.959	95.9	44	1.000	1.000	1.000	1.000	1.000	1.000	0.977
Total	I	--	--	--	--	--	--	10	336	0.702		93	1.000	0.817	0.763	0.634	0.505	0.419	0.355
	D	--	--	--	--	--	--	10	276	0.707	100.7	122	1.000	0.902	0.844	0.803	0.746	0.705	0.639

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

TABLE D-19 INITIAL AND LATENT SURVIVAL OF MONOCULODES EDWARDSI AT THE BOWLINE POINT PLANT, HUDSON RIVER ESTUARY, 1976

Date	Station	Mean Temp.	Temp. Range	DO (mg/ℓ)	Cond. (μMHOS)	pH	Salinity (ppt)	Number Samples	Number Collected	Initial Prop. Surviving	Entrain. Survival, S_e*	Latent Effects Subsample	Extended Survival				
													Initial	24	48	72	96
8 MAR	I	3.2	--	13.4	11	7.7	--	1	16	0.938		13	1.000	0.385	0.385	0.385	0.308
	D	11.0	--	12.3	129	7.4	--	1	16	0.938	100.0	12	1.000	0.500	0.417	0.333	0.333
23 MAR	I	5.3	--	12.7	250	7.8	--	1	103	1.000		70	1.000	0.900	0.900	0.900	0.900
	D	14.1	--	11.3	290	7.9	--	1	151	0.960	96.0	58	1.000	0.948	0.948	0.948	0.948
5 APR	I	7.8	--	10.9	120	7.9	--	1	178	0.899		43	1.000	0.256	0.209	0.209	0.209
	D	16.8	--	9.7	160	7.9	--	1	35	0.829	92.2	20	1.000	0.600	0.550	0.550	0.550
26 APR	I	10.6	--	9.8	58	7.9	--	1	19	0.895		8	1.000	1.000	1.000	1.000	1.000
	D	19.5	--	9.3	67	7.8	--	1	7	0.857	--	5	1.000	1.000	1.000	1.000	1.000
10 MAY	I	15.8	--	9.5	130	7.5	--	1	16	0.688		6	1.000	0.167	0.000	0.000	0.000
	D	25.2	--	9.0	170	7.9	--	1	85	1.000	100.0	0	--	--	--	--	--
24 MAY	I	16.5	--	9.6	130	7.2	--	1	1	1.000		1	1.000	0.000	0.000	0.000	0.000
	D	23.5	--	--	--	--	--	1	11	1.000	--	2	1.000	1.000	1.000	1.000	0.000
7 JUN	D	23.5	--	--	--	--	--	1	15	0.933	--	6	1.000	0.667	0.333	0.167	0.000
21 JUN	I	23.9	22.8-25.0	--	165	--	--	2	5	0.800		0	--	--	--	--	--
	D	30.0	28.0-32.0	--	--	--	--	2	9	0.778	--	3	--	--	--	--	--
12-13 JUL	I	25.6	25.1-26.0	7.5	250	7.9	--	2	6	1.000		0	--	--	--	--	--
	D	30.2	30.0-30.3	--	--	--	--	2	10	1.000	--	0	--	--	--	--	--
26 JUL	I	24.5	--	5.8	792	--	--	1	2	1.000		0	--	--	--	--	--
	D	34.0	--	--	--	--	--	1	3	0.667	--	2	1.000	1.000	1.000	1.000	1.000
9 AUG	I	25.0	--	--	2,700	--	2.0	1	26	0.923		6	1.000	1.000	1.000	1.000	1.000
	D	32.0	--	--	2,450	--	2.0	1	19	0.947	100.0	0					
23 AUG	I	26.0	--	8.2	4,030	--	3.0	1	61	0.967		19	1.000	1.000	1.000	1.000	0.842
	D	35.0	--	9.2	4,030	--	3.0	1	45	0.956	98.9	18	1.000	0.944	0.833	0.833	0.833
13 SEP	I	23.5	--	7.3	2,020	7.5	--	1	7	1.000		6	1.000	0.667	0.667	0.667	0.333
	D	33.0	--	--	2,010	7.3	--	1	2	1.000	--	0	--	--	--	--	--
27 SEP	I	21.0	--	--	--	--	--	1	1	1.000		0	--	--	--	--	--
	D	29.0	--	--	--	7.8	--	1	1	1.000	--	0	--	--	--	--	--
4 OCT	I	18.9	--	7.9	335	7.4	--	1	2	1.000		1	1.000	1.000	1.000	1.000	1.000
	D	28.3	--	7.6	405	6.7	--	1	2	0.500	--	1	1.000	1.000	1.000	1.000	1.000

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

TABLE D-19 (CONT.)

Date	Station	Mean Temp.	Temp. Range	DO (mg/ℓ)	Cond. (μMHOS)	pH	Salinity (ppt)	Number Samples	Number Collected	Initial Prop. Sur- viving	Entrain. Survival, S_e*	Latent Effects Sub- sample	Extended Survival Initial	24	48	72	96
25 OCT	I	12.8	--	9.3	250	--	--	1	2	0.500		0	--	--	--	--	--
	D	24.7	--	9.0	280	--	--	1	2	1.000	--	2	1.000	1.000	1.000	1.000	1.000
1 NOV	I	10.0	--	9.9	160	--	--	1	1	1.000		1	1.000	1.000	1.000	1.000	1.000
	D	20.9	--	9.6	200	--	--	1	4	0.750	--	2	1.000	0.500	0.500	0.500	0.500
15 NOV	I	7.1	--	10.2	150	7.9	--	1	3	1.000		0	--	--	--	--	--
	D	19.6	--	9.9	200	7.8	--	1	8	0.875	--	3	1.000	0.667	0.667	0.667	0.667
6 DEC	I	3.6	--	10.9	970	7.9	--	1	1	1.000		1	1.000	1.000	1.000	1.000	1.000
	D	16.1	--	10.5	1,250	7.9	--	1	1	1.000	--	1	1.000	1.000	1.000	1.000	1.000
Total	I	--	--	--	--	--	--	20	450	0.929		175	1.000	0.686	0.674	0.669	0.623
	D	--	--	--	--	--	--	21	426	0.944	101.6	132	1.000	0.833	0.773	0.773	0.750

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

TABLE D-20 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG YEAR, STATION, AND INITIAL AND 24-HOUR SURVIVAL FOR MONOCULODES EDWARDSI COLLECTED AT THE BOWLINE POINT PLANT, 1975 AND 1976

INITIAL

Source	df	G
Year x station independence	1	1.81
Station x survival independence	1	0.94
Year x survival independence	1	145.29**
Year x station x survival interaction	1	-0.12
Year x station x survival independence	4	147.91**

24-HOUR

Source	df	G
Year x station independence	1	9.58*
Station x survival independence	1	15.74**
Year x survival independence	1	0.24
Year x station x survival interaction	1	0.86
Year x station x survival independence	4	26.42**

Note:

df = degrees of freedom
G = test statistic
* denotes $p \leq 0.05$
** denotes $p \leq 0.001$

TABLE D-21 CORRELATION COEFFICIENTS OF INITIAL AND LATENT SURVIVAL VS. TEMPERATURE AND CONDUCTIVITY OF *MONOCULODES EDWARDSI* COLLECTED AT THE BOWLINE POINT PLANT, 1975 AND 1976

	Temperature				Conductivity	
	1975		1976		1976	
	r	n	r	n	r	n
Initial						
Intake	-0.472	9	-0.001	18	0.186	17
Discharge	-0.276	9	-0.124	19	0.290	13
24-Hours						
Intake	-0.251	7	-0.057	13	0.372	13
Discharge	-0.181	8	0.021	14	-0.132	11

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r = correlation coefficient
n = sample size
** = significant at 0.50 level.

TABLE D-22 INITIAL AND LATENT SURVIVAL OF CRANGON SEPTEMSPINOSA AT THE BOWLINE POINT PLANT, HUDSON RIVER ESTUARY, 1975, 1976 AND 1978

Date	Station	Mean Temp.	Temp. Range	DO (mg/ℓ)	Cond. (UMHOS)	pH	Salinity (ppt)	Number Samples	Number Collected	Initial Proportion Surviving	Entrainment Survival, S_e*	Latent Effects Subsample	Extended Survival							
													Initial	3	6	12	24	48	72	96
1975																				
31 JUL	D	36.0	--	--	--	--	--	1	1	0.000	--	0	--	--	--	--	--	--	--	--
1976																				
4 OCT	I	18.9	--	7.9	335	7.4	--	1	1	1.000	--	1	1.000	--	--	--	1.000	1.000	1.000	1.000
25 OCT	I	12.8	--	9.3	250	--	--	1	2	1.000	--	2	1.000	--	--	--	0.000	0.000	0.000	0.000
1978																				
18 JUL	I	24.8	--	3.9	13,820	8.0	0.7	1	2	1.000	--	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
14 AUG	I	26.5	--	--	6,000	6.8	3.4	1	2	1.000	--	2	1.000	1.000	1.000	1.000	1.000	1.000	0.500	0.500
28 AUG	I	26.6	25.9-27.0	7.1	7,770	7.5	4.3	2	4	0.500	--	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11 SEP	I	23.8	--	6.8	10,850	7.5	6.1	1	1	1.000		1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	D	34.0	--	--	--	--	--	1	1	1.000	--	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
25 SEP	I	21.9	--	7.0	6,820	7.5	4.0	1	1	1.000		1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	D	28.0	--	--	--	--	--	1	1	0.000	--	0								
16 OCT	D	26.6	26.0-27.0	--	--	--	--	3	9	0.000	--	0	--	--	--	--	--	--	--	--
Total	I	--	--	--	--	--	--	8	13	0.846		11	1.000	1.000	1.000	1.000	1.000	1.000	0.909	0.909
	D	--	--	--	--	--	--	6	12	0.083	9.8	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

TABLE D-23 INITIAL AND LATENT SURVIVAL OF UNIDENTIFIED DIPTERA, *LEPTOCHEIRUS PLUMULOSUS*, AND *EDOTEA TRILOBA* AT THE BOWLINE POINT PLANT, HUDSON RIVER ESTUARY, 1975 AND 1976

Year	Station	Months Collected	Number Samples	Maximum Number Collected	Total Number Collected	Initial Prop. Surviving	Entrain. Survival, S_e*	Latent Effects Subsample	Extended Survival						
									Initial	6	12	24	48	72	96
Unidentified Diptera															
1975	I	JUL-OCT, DEC	10	88	129	0.550		37	1.000	0.838	0.459	0.378	0.351	0.351	0.351
	D	JUL-OCT	7	7	25	0.520	94.5	3	1.000	0.667	0.667	0.667	0.667	0.667	0.667
1976	I	APR-OCT	14	13	77	0.753		36	1.000	--	--	0.639	0.611	0.611	0.611
	D	APR-OCT	13	100	189	0.799	100.0	42	1.000	--	--	0.262	0.238	0.238	0.214
Combined	I	APR-OCT, DEC	24	88	206	0.612		73	1.000	--	--	0.507	0.479	0.479	0.479
	D	APR-OCT	20	100	214	0.766	125.2	45	1.000	--	--	0.289	0.267	0.267	0.244
Leptocheirus plumulosus															
1975	I	JUL-SEP, DEC	4	16	21	0.571		10	1.000	1.000	0.800	0.700	0.700	0.600	0.600
	D	JUL-SEP, DEC	5	5	11	1.000	100.0	10	1.000	0.900	0.900	0.900	0.900	0.900	0.900
1976	I	MAR-JUN, NOV	7	27	48	0.938		45	1.000	--	--	0.733	0.578	0.467	0.400
	D	MAR, MAY, JUN, AUG, NOV	6	2	8	0.875	--	5	1.000	--	--	1.000	0.800	0.800	0.800
Combined	I	MAR-SEP, NOV, DEC	11	16	69	0.826		55	1.000	--	--	0.727	0.600	0.491	0.436
	D	MAR, MAY-SEP, NOV, DEC	11	5	19	0.747	114.6	15	1.000	--	--	0.933	0.867	0.867	0.867
Edotea triloba															
1975	I	JUL-OCT	6	46	62	0.935		46	1.000	0.957	0.891	0.500	0.196	0.153	0.153
	D	JUL, SEP, OCT	5	16	39	0.974	100.0	38	1.000	0.974	0.895	0.421	0.289	0.053	0.053
1976	I	SEP	1	1	1	1.000		1	1.000	--	--	1.000	1.000	1.000	1.000
	D	AUG, SEP, OCT	3	1	3	1.000	--	3	1.000	--	--	0.667	0.667	0.667	0.667
Combined	I	JUL-OCT	7	46	63	0.937		47	1.000	--	--	0.511	0.213	0.170	0.170
	D	JUL-OCT	8	16	42	0.976	104.7	41	1.000	--	--	0.439	0.317	0.098	0.098

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

TABLE D-24 INITIAL AND LATENT SURVIVAL OF *COROPHIUM TUBERCULATUM*, *MELITA NITIDA*, *ZOEA*, AND *CYATHURA POLITA* AT THE BOWLINE POINT PLANT, HUDSON RIVER ESTUARY, 1975 AND 1976

Year	Station	Months Collected	Number Samples	Maximum Number Collected	Total Number Collected	Initial Prop. Surviving	Entrain. Survival, S_e*	Latent Effects Subsample	Extended Survival						
									Initial	6	12	24	48	72	96
						Corophium tuberculatum									
1975	I	JUL-SEP, DEC	6	9	22	0.818		6	1.000	0.833	0.833	0.833	0.667	0.667	0.667
	D	JUL-OCT	9	16	71	0.732	89.5	31	1.000	0.935	0.903	0.839	0.645	0.548	0.387
1976	I	AUG-NOV	8	23	70	0.857		25	1.000	--	--	0.880	0.880	0.800	0.640
	D	AUG-DEC	9	50	85	0.894	100.0	39	1.000	--	--	0.897	0.821	0.718	0.641
Combined	I	JUL-DEC	14	23	92	0.847		31	1.000	--	--	0.871	0.871	0.774	0.645
	D	JUL-DEC	18	50	156	0.821	96.9	70	1.000	--	--	0.871	0.742	0.657	0.629
						Melita nitida									
1975	I	JUL-SEP	6	3	9	1.000		5	1.000	1.000	1.000	0.800	0.800	0.800	0.800
	D	AUG-OCT	3	3	6	0.667	--	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1976	I	OCT, NOV	2	3	4	1.000	--	4	1.000	--	--	1.000	1.000	0.750	0.750
Combined	I	JUL-NOV	8	3	13	1.000		9	1.000	--	--	0.889	0.889	0.778	0.778
	D	AUG-OCT	3	3	6	0.667	--	2	1.000	--	--	1.000	1.000	1.000	1.000
						Zoea									
1975	I	JUL-AUG	3	105	128	0.710		49	1.000	1.000	0.939	0.918	0.796	0.694	0.429
	D	JUL-AUG	3	78	95	0.832	100.0	41	1.000	1.000	1.000	0.951	0.878	0.707	0.585
1976	I	JUL-AUG	3	19	30	0.967		13	1.000	--	--	0.769	0.769	0.307	0.231
	D	JUL-AUG	3	62	64	0.859	88.8	35	1.000	--	--	0.971	0.971	0.943	0.886
Combined	I	JUL-AUG	6	105	158	0.759		62	1.000	--	--	0.887	0.790	0.613	0.387
	D	JUL-AUG	6	78	159	0.843	111.1	76	1.000	--	--	0.961	0.921	0.816	0.724
						Cyathura polita									
1975	I	JUL, SEP, OCT	3	5	7	1.000		7	1.000	1.000	1.000	1.000	1.000	1.000	1.000

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

TABLE D-25 INITIAL AND LATENT SURVIVAL OF CHIRIDOTEA ALMYRA, PALAEMONETES SPP., UNIONICOLA SPP., MEGALOPA, AND EPHEMEROPTERA AT THE BOWLINE POINT PLANT, HUDSON RIVER ESTUARY, 1975 AND 1976

Year	Station	Months Collected	Number Samples	Maximum Number Collected	Total Number Collected	Initial Prop. Surviving	Entrain. Survival, S_e*	Latent Effects Subsample	Extended Survival						
									Initial	6	12	24	48	72	96
						Chiridotea almyra									
1976	I	APR, JUN-AUG, OCT	8	8	19	1.000		19	1.000	--	--	1.000	1.000	0.947	0.895
	D	JUN-AUG	6	5	11	1.000	100.0	11	1.000	--	--	1.000	1.000	1.000	0.909
						Palaemonetes spp.									
1975	I	SEP	2	2	3	1.000	--	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1976	I	AUG, OCT	2	1	2	1.000		1	1.000	--	--	1.000	1.000	1.000	1.000
	D	SEP	1	1	1	1.000	--	1	1.000	--	--	1.000	1.000	1.000	1.000
Combined	I	AUG-OCT	4	2	5	1.000		4	1.000	--	--	1.000	1.000	1.000	1.000
	D	SEP	1	1	1	1.000	--	1	1.000	--	--	1.000	1.000	1.000	1.000
						Unionicola spp.									
1975	I	SEP	2	1	2	1.000		1	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	D	SEP	1	1	1	1.000	--	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1976	I	MAY	1	1	1	1.000	--	1	1.000	--	--	1.000	1.000	1.000	1.000
Combined	I	MAY, SEP	3	1	3	1.000		2	1.000	--	--	1.000	1.000	1.000	1.000
	D	SEP	1	1	1	1.000	--	1	1.000	--	--	1.000	1.000	1.000	1.000
						Megalopa									
1976	D	AUG, SEP	3	1	3	0.667	--	1	1.000	--	--	1.000	1.000	1.000	1.000
						Ephemeroptera									
1976	D	SEP, OCT	2	4	8	1.000	--	1	1.000	--	--	1.000	1.000	1.000	1.000

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* S_e for individual dates have a maximum of 1.000; however, yearly totals can be greater than 1.000.

APPENDIX E

DAILY AVERAGE DENSITIES FOR THE MOST ABUNDANT TAXA COLLECTED DURING DISCHARGE ENTRAINMENT ABUNDANCE SAMPLING AT THE BOWLINE POINT PLANT, 1979

TABLE E-1 DAILY AVERAGE DENSITY OF BAY ANCHOVY COLLECTED AT THE BOWLINE POINT PLANT, 1979

				DAILY AVERAGE DENSITY (NO./1000 CU M)					
DATE	AVERAGE TEMPERATURE (DEGREES C)	AVERAGE CONDUCTIVITY (MICROMHOS)	TOTAL VOLUME (CU M)	EGGS	YOLK-SAC LARVAE	LARVAE	JUVENILES	UID	TOTAL (EXCLUDING EGGS)
05/21/79	18.1	630.	101.6	0.0	0.0	0.0	0.0	0.0	0.0
05/24/79	17.9	1086.	72.4	0.0	0.0	0.0	0.0	0.0	0.0
05/29/79	18.0	394.	99.4	0.0	0.0	0.0	0.0	0.0	0.0
05/31/79	18.7	202.	48.6	0.0	0.0	0.0	0.0	0.0	0.0
06/04/79	20.0	140.	99.6	0.0	0.0	0.0	0.0	0.0	0.0
06/07/79	21.5	1930.	68.7	0.0	0.0	0.0	0.0	0.0	0.0
06/11/79	21.0	3849.	517.5	17.4	0.0	9.7	0.0	0.0	9.7
06/12/79	20.3	3000.	450.2	0.0	0.0	8.9	0.0	0.0	8.9
06/13/79	20.7	2200.	518.0	0.0	0.0	5.8	0.0	0.0	5.8
06/14/79	22.0	1678.	506.4	0.0	0.0	0.0	0.0	0.0	0.0
06/15/79	22.2	1550.	449.2	0.0	0.0	8.9	0.0	0.0	8.9
06/18/79	23.7	1161.	517.3	0.0	0.0	1.9	0.0	0.0	1.9
06/19/79	22.9	1130.	593.4	0.0	0.0	0.0	0.0	0.0	0.0
06/20/79	23.5	1160.	598.1	0.0	0.0	1.7	0.0	0.0	1.7
06/21/79	23.8	1287.	602.6	0.0	0.0	1.7	0.0	0.0	1.7
06/22/79	23.2	1870.	544.5	0.0	0.0	27.5	0.0	0.0	27.5
06/25/79	22.3	1958.	563.3	0.0	0.0	49.7	0.0	0.0	49.7
06/26/79	22.1	2610.	617.2	0.0	0.0	59.9	0.0	0.0	59.9
06/27/79	22.3	2560.	602.8	0.0	0.0	121.1	0.0	0.0	121.1
06/28/79	23.0	2309.	599.2	0.0	0.0	223.6	0.0	0.0	223.6
06/29/79	23.6	2380.	518.1	0.0	0.0	23.2	0.0	0.0	23.2
07/01/79	23.2	2760.	527.0	0.0	0.0	242.9	0.0	0.0	242.9
07/02/79	23.6	2865.	584.4	0.0	0.0	455.2	0.0	0.0	455.2
07/05/79	22.3	5019.	580.4	1.7	0.0	570.3	0.0	0.0	570.3
07/06/79	21.9	6560.	553.0	36.2	0.0	350.8	0.0	0.0	350.8
07/07/79	22.6	7660.	559.7	25.0	0.0	607.5	0.0	0.0	607.5
07/08/79	23.1	8350.	560.2	42.8	3.6	803.3	0.0	0.0	806.9
07/09/79	23.4	8628.	584.0	47.9	0.0	1371.6	0.0	0.0	1371.6
07/10/79	23.5	8820.	580.4	20.7	0.0	1247.4	0.0	0.0	1247.4
07/11/79	24.2	9200.	595.2	28.6	0.0	1090.4	1.7	0.0	1092.1
07/12/79	24.2	8690.	583.0	15.4	0.0	1521.4	0.0	0.0	1521.4

TABLE E-2 DAILY AVERAGE DENSITY OF STRIPED BASS COLLECTED AT THE BOWLINE POINT PLANT, 1979

				DAILY AVERAGE DENSITY (NO./1000 CU M)					
DATE	AVERAGE TEMPERATURE (DEGREES C)	AVERAGE CONDUCTIVITY (MICROMHOS)	TOTAL VOLUME (CU M)	EGGS	YOLK-SAC LARVAE	LARVAE	JUVENILES	UID	TOTAL (EXCLUDING EGGS)
05/21/79	18.1	630.	101.6	0.0	0.0	0.0	0.0	0.0	0.0
05/24/79	17.9	1086.	72.4	0.0	0.0	0.0	0.0	0.0	0.0
05/29/79	18.0	394.	99.4	0.0	0.0	0.0	0.0	0.0	0.0
05/31/79	18.7	202.	48.6	0.0	0.0	41.2	0.0	0.0	41.2
06/04/79	20.0	140.	99.6	0.0	0.0	10.0	0.0	0.0	10.0
06/07/79	21.5	1930.	68.7	0.0	0.0	0.0	0.0	0.0	0.0
06/11/79	21.0	3849.	517.5	0.0	7.7	50.2	0.0	0.0	58.0
06/12/79	20.3	3000.	450.2	0.0	37.8	57.8	0.0	0.0	95.5
06/13/79	20.7	2200.	518.0	0.0	32.8	17.4	0.0	0.0	50.2
06/14/79	22.0	1678.	506.4	0.0	33.6	27.6	0.0	0.0	61.2
06/15/79	22.2	1550.	449.2	0.0	69.0	84.6	0.0	0.0	153.6
06/18/79	23.7	1161.	517.3	0.0	48.3	166.2	7.7	0.0	222.3
06/19/79	22.9	1130.	593.4	0.0	1.7	20.2	0.0	0.0	21.9
06/20/79	23.5	1160.	598.1	0.0	0.0	36.8	0.0	0.0	36.8
06/21/79	23.8	1287.	602.6	0.0	14.9	68.0	10.0	0.0	92.9
06/22/79	23.2	1870.	544.5	0.0	0.0	16.5	12.9	0.0	29.4
06/25/79	22.3	1958.	563.3	0.0	0.0	28.4	39.1	0.0	67.5
06/26/79	22.1	2610.	617.2	0.0	0.0	3.2	21.1	0.0	24.3
06/27/79	22.3	2560.	602.8	0.0	0.0	10.0	14.9	0.0	24.9
06/28/79	23.0	2309.	599.2	0.0	0.0	15.0	13.4	0.0	28.4
06/29/79	23.6	2380.	518.1	0.0	0.0	11.6	0.0	0.0	11.6
07/01/79	23.2	2760.	527.0	0.0	1.9	5.7	7.6	0.0	15.2
07/02/79	23.6	2865.	584.4	0.0	0.0	5.1	1.7	0.0	6.8
07/05/79	22.3	5019.	580.4	0.0	0.0	1.7	6.9	0.0	8.6
07/06/79	21.9	6560.	553.0	0.0	0.0	0.0	3.6	0.0	3.6
07/07/79	22.6	7660.	559.7	0.0	0.0	0.0	1.8	0.0	1.8
07/08/79	23.1	8350.	560.2	0.0	0.0	0.0	5.4	0.0	5.4
07/09/79	23.4	8628.	584.0	0.0	0.0	0.0	0.0	0.0	0.0
07/10/79	23.5	8820.	580.4	0.0	0.0	0.0	1.7	0.0	1.7
07/11/79	24.2	9200.	595.2	0.0	0.0	1.7	3.4	0.0	5.0
07/12/79	24.2	8690.	583.0	0.0	0.0	0.0	1.7	0.0	1.7

TABLE E-3 DAILY AVERAGE DENSITY OF WHITE PERCH COLLECTED AT THE BOWLINE POINT PLANT, 1979

DATE	AVERAGE TEMPERATURE (DEGREES C)	AVERAGE CONDUCTIVITY (MICROMHOS)	TOTAL VOLUME (CU M)	DAILY AVERAGE DENSITY (NO./1000 CU M)					
				EGGS	YOLK-SAC LARVAE	LARVAE	JUVENILES	UID	TOTAL (EXCLUDING EGGS)
05/21/79	18.1	630.	101.6	19.7	0.0	9.8	0.0	0.0	9.8
05/24/79	17.9	1086.	72.4	82.9	0.0	0.0	0.0	0.0	0.0
05/29/79	18.0	394.	99.4	161.0	0.0	0.0	0.0	0.0	0.0
05/31/79	18.7	202.	48.6	82.3	0.0	20.6	0.0	0.0	20.6
06/04/79	20.0	140.	99.6	80.3	10.0	90.4	0.0	0.0	100.4
06/07/79	21.5	1930.	68.7	14.6	0.0	29.1	0.0	0.0	29.1
06/11/79	21.0	3849.	517.5	25.1	15.5	38.6	0.0	0.0	54.1
06/12/79	20.3	3000.	450.2	35.5	11.1	64.4	0.0	0.0	75.5
06/13/79	20.7	2200.	518.0	34.7	1.9	63.7	0.0	0.0	65.6
06/14/79	22.0	1678.	506.4	35.5	13.8	92.8	0.0	0.0	106.6
06/15/79	22.2	1550.	449.2	17.8	20.0	173.6	0.0	0.0	193.7
06/18/79	23.7	1161.	517.3	15.5	13.5	63.8	0.0	0.0	77.3
06/19/79	22.9	1130.	593.4	3.4	8.4	23.6	0.0	0.0	32.0
06/20/79	23.5	1160.	598.1	6.7	5.0	16.7	3.3	0.0	25.1
06/21/79	23.8	1287.	602.6	1.7	28.2	48.1	1.7	0.0	78.0
06/22/79	23.2	1870.	544.5	0.0	0.0	9.2	1.8	0.0	11.0
06/25/79	22.3	1958.	563.3	8.9	1.8	30.2	12.4	0.0	44.4
06/26/79	22.1	2610.	617.2	3.2	1.6	0.0	3.2	0.0	4.9
06/27/79	22.3	2560.	602.8	1.7	0.0	0.0	0.0	0.0	0.0
06/28/79	23.0	2309.	599.2	3.3	0.0	3.3	0.0	0.0	3.3
06/29/79	23.6	2380.	518.1	0.0	0.0	0.0	0.0	0.0	0.0
07/01/79	23.2	2760.	527.0	0.0	0.0	0.0	0.0	0.0	0.0
07/02/79	23.6	2865.	584.4	1.7	0.0	6.8	0.0	0.0	6.8
07/05/79	27.3	5019.	580.4	0.0	0.0	0.0	0.0	0.0	0.0
07/06/79	21.9	6560.	553.0	0.0	0.0	0.0	0.0	0.0	0.0
07/07/79	22.6	7660.	559.7	0.0	0.0	0.0	0.0	0.0	0.0
07/08/79	23.1	8350.	560.2	0.0	0.0	0.0	0.0	0.0	0.0
07/09/79	23.4	8628.	584.0	0.0	0.0	0.0	0.0	0.0	0.0
07/10/79	23.5	8820.	580.4	0.0	0.0	0.0	0.0	0.0	0.0
07/11/79	24.2	9200.	595.2	0.0	0.0	1.7	0.0	0.0	1.7
07/12/79	24.2	8690.	583.0	0.0	0.0	3.4	0.0	0.0	3.4

TABLE E-4 DAILY AVERAGE DENSITY OF ATLANTIC TOMCOD COLLECTED AT THE BOWLINE POINT PLANT, 1979

				DAILY AVERAGE DENSITY (NO./1000 CU M)					
DATE	AVERAGE TEMPERATURE (DEGREES C)	AVERAGE CONDUCTIVITY (MICROMHOS)	TOTAL VOLUME (CU M)	EGGS	YOLK-SAC LARVAE	LARVAE	JUVENILES	UID	TOTAL (EXCLUDING EGGS)
03/05/79	1.0	125.	557.6	0.0	0.0	0.0	0.0	16.1	16.1
03/06/79	1.2	129.	572.6	0.0	1.7	10.5	0.0	27.9	40.2
03/07/79	3.0	103.	584.2	0.0	1.7	1.7	0.0	29.1	32.5
03/08/79	2.0	120.	582.5	0.0	3.4	0.0	0.0	22.3	25.8
03/09/79	2.0	120.	573.6	0.0	1.7	1.7	0.0	17.4	20.9
03/12/79	0.4	90.	510.9	0.0	7.8	7.8	0.0	37.2	52.8
03/13/79	1.2	93.	552.4	0.0	23.5	16.3	0.0	83.3	123.1
03/14/79	1.3	88.	542.5	0.0	14.7	9.2	0.0	55.3	79.3
03/15/79	0.6	84.	517.4	0.0	30.9	30.9	0.0	141.1	202.9
03/16/79	0.6	84.	527.2	0.0	30.3	30.3	0.0	85.4	146.1
03/19/79	2.8	86.	544.7	0.0	22.0	25.7	0.0	143.2	190.9
03/20/79	3.3	91.	541.9	0.0	11.1	51.7	0.0	204.8	267.6
03/21/79	3.9	165.	563.8	0.0	10.6	40.8	0.0	129.5	180.9
03/22/79	4.0	279.	549.7	0.0	3.6	21.8	0.0	98.2	123.7
03/23/79	3.9	279.	548.2	0.0	0.0	32.8	0.0	58.4	91.2
03/26/79	3.9	119.	557.9	0.0	3.6	19.7	0.0	102.2	125.5
03/27/79	4.0	109.	529.1	0.0	3.8	81.3	0.0	236.3	321.3
03/28/79	4.5	110.	559.3	0.0	0.0	34.0	0.0	98.3	132.3
03/29/79	5.1	112.	565.7	0.0	0.0	17.7	0.0	79.5	97.2

TABLE E-5 DAILY AVERAGE DENSITY OF CLUPEIDS COLLECTED AT THE BOWLINE POINT PLANT, 1979

DATE	AVERAGE TEMPERATURE (DEGREES C)	AVERAGE CONDUCTIVITY (MICROMHOS)	TOTAL VOLUME (CU M)	DAILY AVERAGE DENSITY (NO./1000 CU M)					
				EGGS	YOLK-SAC LARVAE	LARVAE	JUVENILES	UID	TOTAL (EXCLUDING EGGS)
05/21/79	18.1	630.	101.6	0.0	0.0	29.5	0.0	0.0	29.5
05/24/79	17.9	1086.	72.4	0.0	0.0	0.0	0.0	0.0	0.0
05/29/79	18.0	394.	99.4	0.0	0.0	20.1	0.0	0.0	20.1
05/31/79	18.7	202.	48.6	0.0	0.0	20.6	0.0	0.0	20.6
06/04/79	20.0	140.	99.6	0.0	0.0	160.6	0.0	0.0	160.6
06/07/79	21.5	1930.	68.7	0.0	0.0	43.7	0.0	0.0	43.7
06/11/79	21.0	3849.	517.5	0.0	0.0	25.1	0.0	0.0	25.1
06/12/79	20.3	3000.	450.2	0.0	0.0	15.5	0.0	0.0	15.5
06/13/79	20.7	2200.	518.0	0.0	0.0	13.5	0.0	0.0	13.5
06/14/79	22.0	1678.	506.4	0.0	0.0	11.8	0.0	0.0	11.8
06/15/79	22.2	1550.	449.2	0.0	0.0	17.8	0.0	0.0	17.8
06/18/79	23.7	1161.	517.3	0.0	0.0	3.9	0.0	0.0	3.9
06/19/79	22.9	1130.	593.4	0.0	0.0	15.2	0.0	0.0	15.2
06/20/79	23.5	1160.	598.1	0.0	0.0	3.3	0.0	0.0	3.3
06/21/79	23.8	1287.	602.6	0.0	0.0	16.6	0.0	0.0	16.6
06/22/79	23.2	1870.	544.5	0.0	0.0	1.8	0.0	0.0	1.8
06/25/79	22.3	1958.	563.3	0.0	0.0	3.6	0.0	0.0	3.6
06/26/79	22.1	2610.	617.2	0.0	0.0	0.0	0.0	0.0	0.0
06/27/79	22.3	2560.	602.8	0.0	0.0	0.0	0.0	0.0	0.0
06/28/79	23.0	2309.	599.2	0.0	0.0	0.0	0.0	0.0	0.0
06/29/79	23.6	2380.	518.1	0.0	0.0	0.0	0.0	0.0	0.0
07/01/79	23.2	2760.	527.0	0.0	0.0	0.0	0.0	0.0	0.0
07/02/79	23.6	2865.	584.4	0.0	0.0	0.0	0.0	0.0	0.0
07/05/79	22.3	5019.	580.4	0.0	0.0	0.0	0.0	0.0	0.0
07/06/79	21.9	6560.	553.0	0.0	0.0	0.0	0.0	0.0	0.0
07/07/79	22.6	7660.	559.7	0.0	0.0	0.0	0.0	0.0	0.0
07/08/79	23.1	8350.	560.2	0.0	0.0	0.0	0.0	0.0	0.0
07/09/79	23.4	8628.	584.0	0.0	0.0	0.0	0.0	0.0	0.0
07/10/79	23.5	8820.	580.4	0.0	0.0	0.0	0.0	0.0	0.0
07/11/79	24.2	9200.	595.2	0.0	0.0	0.0	0.0	0.0	0.0
07/12/79	24.2	8690.	583.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX F

LENGTH DISTRIBUTION OF THE MOST ABUNDANT TAXA COLLECTED DURING DISCHARGE ENTRAINMENT ABUNDANCE SAMPLING AT THE BOWLINE POINT PLANT, 1979

TABLE F-1 LENGTH-FREQUENCY DISTRIBUTION AND WEEKLY MEAN, RANGE, AND STANDARD DEVIATION OF LENGTHS OF BAY ANCHOVY IN COLLECTIONS AT THE DISCHARGE OF THE BOWLINE POINT PLANT, 1979

				LENGTH INTERVALS (MM)									RANGE		
DATE	N	X	SD	0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0 999.9	MIN	MED	MAX
21 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
29 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
4 JUN 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
11 JUN 79	9	5.2	0.9	0	6	3	0	0	0	0	0	0	4.0	5.0	7.0
18 JUN 79	8	6.6	1.4	0	2	6	0	0	0	0	0	0	4.0	7.0	8.0
25 JUN 79	110	10.8	5.0	0	19	29	8	18	26	10	0	0	3.0	10.5	20.0
1 JUL 79	362	13.4	5.9	0	29	62	72	39	39	71	44	6	3.0	13.0	25.0
8 JUL 79	477	11.6	7.4	1	100	147	40	36	31	43	39	40	2.0	8.0	65.0

N=NUMBER OF LENGTHS; MIN=SHORTEST LENGTH
X=MEAN LENGTH; MED=MEDIAN LENGTH
SD=STANDARD DEVIATION; MAX=GREATEST LENGTH
NA=DATA NOT AVAILABLE

TABLE F-2 LENGTH-FREQUENCY DISTRIBUTION AND WEEKLY MEAN, RANGE, AND STANDARD DEVIATION OF LENGTHS OF STRIPED BASS IN COLLECTIONS AT THE DISCHARGE OF THE BOWLINE POINT PLANT, 1979

				LENGTH INTERVALS (MM)									RANGE		
DATE	N	X	SD	0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0 999.9	MIN	MED	MAX
21 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
29 MAY 79	2	7.5	0.5	0	0	2	0	0	0	0	0	0	7.0	7.5	8.0
4 JUN 79	1	5.0	0.0	0	1	0	0	0	0	0	0	0	5.0	5.0	5.0
11 JUN 79	189	7.6	2.4	0	33	100	41	13	2	0	0	0	4.0	7.0	15.0
18 JUN 79	193	10.9	3.8	0	9	47	62	39	28	6	1	1	5.0	10.0	27.0
25 JUN 79	86	16.5	4.5	0	0	3	12	17	11	27	12	4	6.0	17.5	27.0
1 JUL 79	19	18.5	6.5	0	0	1	4	2	0	1	6	5	6.0	21.0	27.0
8 JUL 79	8	27.5	6.1	0	0	0	0	1	0	0	0	7	13.0	29.5	34.0

N=NUMBER OF LENGTHS; MIN=SHORTEST LENGTH
X=MEAN LENGTH; MED=MEDIAN LENGTH
SD=STANDARD DEVIATION; MAX=GREATEST LENGTH
NA=DATA NOT AVAILABLE

TABLE F-3 LENGTH-FREQUENCY DISTRIBUTION AND WEEKLY MEAN, RANGE, AND STANDARD DEVIATION OF LENGTHS OF WHITE PERCH IN COLLECTIONS AT THE DISCHARGE OF THE BOWLINE POINT PLANT, 1979

				LENGTH INTERVALS (MM)									RANGE		
DATE	N	X	SD	0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0 999.9	MIN	MED	MAX
21 MAY 79	1	4.0	0.0	0	1	0	0	0	0	0	0	0	4.0	4.0	4.0
29 MAY 79	1	5.0	0.0	0	1	0	0	0	0	0	0	0	5.0	5.0	5.0
4 JUN 79	12	5.1	1.4	0	7	5	0	0	0	0	0	0	3.0	4.5	8.0
11 JUN 79	210	4.5	1.5	1	179	26	2	2	0	0	0	0	2.0	4.0	13.0
18 JUN 79	123	5.1	3.1	0	97	11	4	8	3	0	0	0	3.0	4.0	17.0
25 JUN 79	30	9.7	5.7	0	14	1	0	6	7	2	0	0	3.0	9.0	19.0
1 JUL 79	4	7.0	3.0	0	1	2	0	1	0	0	0	0	4.0	6.0	12.0
8 JUL 79	3	13.0	0.0	0	0	0	0	3	0	0	0	0	13.0	13.0	13.0

N=NUMBER OF LENGTHS; MIN=SHORTEST LENGTH
X=MEAN LENGTH; MED=MEDIAN LENGTH
SD=STANDARD DEVIATION; MAX=GREATEST LENGTH
NA=DATA NOT AVAILABLE

TABLE F-4 LENGTH-FREQUENCY DISTRIBUTION AND WEEKLY MEAN, RANGE, AND STANDARD DEVIATION OF LENGTHS OF ATLANTIC TOMCOD IN COLLECTIONS AT THE DISCHARGE OF THE BOWLINE POINT PLANT, 1979

				LENGTH INTERVALS (MM)									RANGE		
DATE	N	X	SD	0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0 999.9	MIN	MED	MAX
5 MAR 79	42	6.9	0.6	0	0	42	0	0	0	0	0	0	6.0	7.0	8.0
12 MAR 79	198	7.1	0.6	0	0	198	0	0	0	0	0	0	6.0	7.0	8.0
19 MAR 79	293	7.2	0.7	0	0	282	11	0	0	0	0	0	6.0	7.0	9.0
26 MAR 79	244	7.0	0.6	0	0	244	0	0	0	0	0	0	6.0	7.0	8.0

N=NUMBER OF LENGTHS;
X=MEAN LENGTH;
SD=STANDARD DEVIATION;
NA=DATA NOT AVAILABLE

MIN=SHORTEST LENGTH
MED=MEDIAN LENGTH
MAX=GREATEST LENGTH

TABLE F-5 LENGTH-FREQUENCY DISTRIBUTION AND WEEKLY MEAN, RANGE, AND STANDARD DEVIATION OF LENGTHS OF CLUPEIDS IN COLLECTIONS AT THE DISCHARGE OF THE BOWLINE POINT PLANT, 1979

				LENGTH INTERVALS (MM)									RANGE		
DATE	N	X	SD	0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0 999.9	MIN	MED	MAX
21 MAY 79	3	6.7	0.5	0	0	3	0	0	0	0	0	0	6.0	7.0	7.0
29 MAY 79	3	6.7	2.5	0	1	1	1	0	0	0	0	0	4.0	6.0	10.0
4 JUN 79	16	7.1	2.0	0	3	10	2	1	0	0	0	0	5.0	6.5	12.0
11 JUN 79	36	10.5	4.5	0	0	11	18	1	3	1	1	1	6.0	9.0	26.0
18 JUN 79	11	17.2	4.0	0	0	0	0	2	6	2	0	1	12.0	17.0	28.0
25 JUN 79	1	20.0	0.0	0	0	0	0	0	0	1	0	0	20.0	20.0	20.0
1 JUL 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
8 JUL 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0

N=NUMBER OF LENGTHS; MIN=SHORTEST LENGTH
X=MEAN LENGTH; MED=MEDIAN LENGTH
SD=STANDARD DEVIATION; MAX=GREATEST LENGTH
NA=DATA NOT AVAILABLE

APPENDIX G

DIEL DISTRIBUTION OF THE MOST ABUNDANT TAXA COLLECTED DURING DISCHARGE ENTRAINMENT ABUNDANCE SAMPLING AT THE BOWLINE POINT PLANT, 1979

TABLE G-1 DIEL DISTRIBUTION OF BAY ANCHOVY AT THE BOWLINE POINT PLANT DISCHARGE, 1979

Post Yolk-Sac Larvae (No./1,000 m^3)

DATE	0900HR	1200HR	1500HR	1800HR	2100HR	2400HR	0300HR	0600HR
03/06/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/13/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/20/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/27/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/11/79	14.3	15.1	0.0	16.5	0.0	14.3	0.0	17.0
06/15/79	15.6	0.0	15.1	30.4	0.0	0.0	0.0	
06/18/79	0.0	0.0	0.0	14.8	0.0	0.0	0.0	0.0
06/21/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.7
06/25/79	0.0	86.6	42.5	103.9	13.2	14.3	79.7	56.4
06/28/79	186.3	153.5	227.0	86.2	82.1	13.7	513.7	449.6
07/02/79	307.0	363.6	307.2	304.3	489.5	539.7	621.9	712.3
07/05/79	455.9	89.4	203.6	617.1	956.3	420.3	786.0	958.0
07/09/79	2170.6	796.7	949.7	1035.4	1430.4	1880.8	1424.0	1191.4
07/12/79	1421.9	1799.2	1531.9	1988.5	2034.6	1322.4	721.7	1452.8

TABLE G-2 DIEL DISTRIBUTION OF STRIPED BASS AT THE BOWLINE POINT PLANT DISCHARGE, 1979

Post Yolk-Sac Larvae (No./1,000 m^3)

DATE	0900HR	1200HR	1500HR	1800HR	2100HR	2400HR	0300HR	0600HR
03/06/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/13/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/20/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/27/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/11/79	28.6	45.3	16.3	33.1	42.1	114.4	50.5	68.0
06/15/79	31.1	16.8	0.0	0.0	243.9	195.8	97.4	
06/18/79	32.8	50.5	14.9	89.0	61.3	360.7	667.7	69.7
06/21/79	0.0	0.0	0.0	49.1	38.2	151.1	159.4	139.9
06/25/79	15.6	0.0	113.3	14.8	0.0	0.0	66.4	14.1
06/28/79	28.7	12.8	42.6	0.0	0.0	0.0	10.9	27.2
07/02/79	0.0	0.0	0.0	0.0	0.0	0.0	25.4	14.0
07/05/79	0.0	0.0	13.6	0.0	0.0	0.0	0.0	0.0
07/09/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/12/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Yolk-Sac Larvae (No./1,000 m^3)

DATE	0900HR	1200HR	1500HR	1800HR	2100HR	2400HR	0300HR	0600HR
03/06/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/13/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/20/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/27/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/11/79	0.0	0.0	0.0	33.1	0.0	14.3	0.0	17.0
06/15/79	15.6	0.0	0.0	45.6	106.7	120.5	194.8	
06/18/79	65.6	50.5	74.5	0.0	15.3	49.2	77.6	55.8
06/21/79	38.7	0.0	0.0	0.0	0.0	0.0	66.4	12.7
06/25/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/28/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/02/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/05/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/09/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/12/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE G-2 (CONT.)

Juveniles (No./1,000 m^3)

DATE	0900HR	1200HR	1500HR	1800HR	2100HR	2400HR	0300HR	0600HR
03/06/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/13/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/20/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/27/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/11/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/15/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
06/18/79	0.0	0.0	0.0	0.0	0.0	16.4	46.6	0.0
06/21/79	0.0	0.0	0.0	0.0	12.7	54.9	13.3	0.0
06/25/79	0.0	0.0	0.0	14.8	39.5	71.7	172.6	0.0
06/28/79	0.0	0.0	0.0	0.0	0.0	27.4	65.6	0.0
07/02/79	0.0	0.0	0.0	0.0	0.0	0.0	12.7	0.0
07/05/79	0.0	0.0	0.0	0.0	41.0	14.5	0.0	0.0
07/09/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/12/79	0.0	0.0	0.0	0.0	0.0	0.0	12.9	0.0

TABLE G-3 DIEL DISTRIBUTION OF WHITE PERCH AT THE BOWLINE POINT PLANT DISCHARGE, 1979

Post Yolk-Sac Larvae (No./1,000 m^3)

DATE	0900HR	1200HR	1500HR	1800HR	2100HR	2400HR	0300HR	0600HR
03/06/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/13/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/20/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/27/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/11/79	14.3	15.1	0.0	99.2	28.1	71.5	50.5	34.0
06/15/79	31.1	134.7	45.4	136.8	259.1	406.6	194.8	
06/18/79	49.2	50.5	74.5	59.3	45.9	65.6	93.2	69.7
06/21/79	38.7	0.0	87.8	85.9	38.2	13.7	39.8	76.3
06/25/79	31.2	14.4	0.0	44.5	0.0	14.3	93.0	42.3
06/28/79	14.3	0.0	0.0	0.0	0.0	0.0	0.0	13.6
07/02/79	0.0	0.0	12.8	27.7	0.0	0.0	12.7	0.0
07/05/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/09/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/12/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.2

Yolk-Sac Larvae (No./1,000 m^3)

DATE	0900HR	1200HR	1500HR	1800HR	2100HR	2400HR	0300HR	0600HR
03/06/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/13/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/20/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/27/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/11/79	0.0	0.0	0.0	16.5	0.0	28.6	50.5	34.0
06/15/79	0.0	0.0	0.0	0.0	15.2	30.1	97.4	
06/18/79	0.0	33.7	29.8	14.8	0.0	0.0	0.0	27.9
06/21/79	38.7	0.0	87.8	49.1	0.0	27.5	13.3	12.7
06/25/79	0.0	14.4	0.0	0.0	0.0	0.0	0.0	0.0
06/28/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/02/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/05/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/09/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/12/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE G-3 (CONT.)

Eggs (No./1,000 m^3)

DATE	0900HR	1200HR	1500HR	1800HR	2100HR	2400HR	0300HR	0600HR
03/06/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/13/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/20/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/27/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/11/79	42.9	0.0	0.0	0.0	42.1	28.6	67.3	17.0
06/15/79	46.7	0.0	15.1	15.2	30.5	0.0	16.2	
06/18/79	0.0	0.0	14.9	14.8	0.0	0.0	93.2	0.0
06/21/79	0.0	0.0	14.6	0.0	0.0	0.0	0.0	0.0
06/25/79	15.6	14.4	14.2	0.0	0.0	0.0	13.3	14.1
06/28/79	14.3	0.0	0.0	0.0	0.0	0.0	10.9	0.0
07/02/79	0.0	0.0	12.8	0.0	0.0	0.0	0.0	0.0
07/05/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/09/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/12/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE G-4 DIEL DISTRIBUTION OF ATLANTIC TOMCOD AT THE BOWLINE POINT PLANT DISCHARGE, 1979

Post Yolk-Sac Larvae (No./1,000 m^3)

DATE	0900HR	1200HR	1500HR	1800HR	2100HR	2400HR	0300HR	0600HR
03/06/79	29.3	27.6	0.0	0.0	28.2	0.0	0.0	0.0
03/13/79	0.0	43.9	31.0	43.5	0.0	0.0	0.0	14.6
03/20/79	62.9	56.8	43.0	15.8	31.3	42.2	82.0	75.0
03/27/79	47.2	45.7	64.3	59.5	164.6	102.6	131.8	29.1
06/11/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/15/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
06/18/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/21/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/25/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/28/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/02/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/05/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/09/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/12/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yolk-Sac Larvae (No./1,000 m^3)								
03/06/79	0.0	0.0	0.0	0.0	0.0	0.0	14.4	0.0
03/13/79	13.5	43.9	0.0	43.5	53.5	29.2	0.0	0.0
03/20/79	31.4	42.6	0.0	0.0	15.7	0.0	0.0	0.0
03/27/79	0.0	0.0	0.0	0.0	13.7	0.0	16.5	0.0
06/11/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/15/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
06/18/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/21/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/25/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/28/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/02/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/05/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/09/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/12/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE G-5 DIEL DISTRIBUTION OF CLUPEIDS AT THE BOWLINE POINT PLANT DISCHARGE, 1979

Post Yolk-Sac Larvae (No./1,000 m^3)

DATE	0900HR	1200HR	1500HR	1800HR	2100HR	2400HR	0300HR	0600HR
03/06/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/13/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/20/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03/27/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06/11/79	0.0	30.2	32.6	66.1	28.1	14.3	0.0	34.0
06/15/79	0.0	33.7	0.0	15.2	30.5	15.1	32.5	
06/18/79	0.0	0.0	0.0	0.0	0.0	16.4	0.0	13.9
06/21/79	25.8	0.0	0.0	49.1	0.0	27.4	26.6	0.0
06/25/79	15.6	0.0	0.0	14.8	0.0	0.0	0.0	0.0
06/28/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/02/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/05/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/09/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07/12/79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX H

DAILY AVERAGE DENSITIES OF THE MOST ABUNDANT TAXA COLLECTED DURING INTAKE ABUNDANCE STUDIES AT THE BOWLINE POINT PLANT, 1979

TABLE H-1 DAILY AVERAGE DENSITIES OF BAY ANCHOVY AT THE BOWLINE POINT PLANT INTAKE, 1979

DATE	AVERAGE TEMPERATURE (DEGREES C)	AVERAGE CONDUCTIVITY (MICROMHOS)	TOTAL VOLUME (CU M)	DAILY AVERAGE DENSITY (NO./1000 CU M)					
				EGGS	YOLK-SAC LARVAE	LARVAE	JUVENILES	UID	TOTAL (EXCLUDING EGGS)
05/21/79	18.1	630.	189.6	0.0	0.0	0.0	0.0	0.0	0.0
05/24/79	18.0	1086.	224.2	0.0	0.0	0.0	0.0	0.0	0.0
05/29/79	18.0	394.	220.7	0.0	0.0	0.0	0.0	0.0	0.0
05/31/79	18.9	184.	249.8	0.0	0.0	0.0	0.0	0.0	0.0
06/04/79	19.9	135.	266.8	0.0	0.0	0.0	0.0	0.0	0.0
06/07/79	21.5	1930.	335.7	0.0	0.0	0.0	0.0	0.0	0.0
06/11/79	21.2	3670.	211.8	4.7	0.0	37.8	0.0	0.0	37.8
06/14/79	21.9	1835.	300.1	0.0	0.0	0.0	0.0	0.0	0.0
06/18/79	23.7	1055.	452.6	0.0	0.0	8.8	0.0	0.0	8.8
06/21/79	24.0	1220.	216.0	0.0	0.0	13.9	0.0	0.0	13.9
06/22/79	23.5	1610.	221.6	0.0	0.0	67.7	0.0	0.0	67.7
06/25/79	22.4	1715.	492.2	0.0	0.0	8.1	0.0	0.0	8.1
06/28/79	23.1	2365.	532.7	0.0	0.0	144.5	0.0	0.0	144.5
07/02/79	23.6	2645.	552.2	0.0	0.0	259.0	0.0	0.0	259.0
07/05/79	22.4	4660.	559.4	0.0	3.6	409.4	0.0	0.0	412.9
07/09/79	23.5	8355.	559.4	0.0	10.7	886.7	0.0	0.0	897.4

TABLE H-2 DAILY AVERAGE DENSITIES OF STRIPED BASS AT THE BOWLINE POINT PLANT INTAKE, 1979

				DAILY AVERAGE DENSITY (NO./1000 CU M)					
DATE	AVERAGE TEMPERATURE (DEGREES C)	AVERAGE CONDUCTIVITY (MICROMHOS)	TOTAL VOLUME (CU M)	EGGS	YOLK-SAC LARVAE	LARVAE	JUVENILES	UID	TOTAL (EXCLUDING EGGS)
05/21/79	18. 1	630.	189. 6	0. 0	0. 0	0. 0	0. 0	0. 0	0. 0
05/24/79	18. 0	1086.	224. 2	0. 0	0. 0	0. 0	0. 0	0. 0	0. 0
05/29/79	18. 0	394.	220. 7	0. 0	0. 0	13. 6	0. 0	0. 0	13. 6
05/31/79	18. 9	184.	249. 8	0. 0	0. 0	4. 0	0. 0	0. 0	4. 0
06/04/79	19. 9	135.	266. 8	0. 0	0. 0	7. 5	0. 0	0. 0	7. 5
06/07/79	21. 5	1930.	335. 7	0. 0	0. 0	20. 9	0. 0	0. 0	20. 9
06/11/79	21. 2	3670.	211. 8	0. 0	14. 2	14. 2	0. 0	0. 0	28. 3
06/14/79	21. 9	1835.	300. 1	0. 0	3. 3	70. 0	0. 0	0. 0	73. 3
06/18/79	23. 7	1055.	452. 6	0. 0	11. 0	44. 2	0. 0	0. 0	55. 2
06/21/79	24. 0	1220.	216. 0	0. 0	0. 0	0. 0	0. 0	0. 0	0. 0
06/22/79	23. 5	1610.	221. 6	0. 0	9. 0	31. 6	9. 0	0. 0	49. 6
06/25/79	22. 4	1715.	492. 2	0. 0	0. 0	2. 0	0. 0	0. 0	2. 0
06/28/79	23. 1	2365.	532. 7	0. 0	0. 0	0. 0	0. 0	0. 0	0. 0
07/02/79	23. 6	2645.	552. 2	0. 0	0. 0	3. 6	1. 8	0. 0	5. 4
07/05/79	22. 4	4660.	559. 4	0. 0	0. 0	0. 0	0. 0	0. 0	0. 0
07/09/79	23. 5	8355.	559. 4	0. 0	0. 0	0. 0	0. 0	0. 0	0. 0

TABLE H-3 DAILY AVERAGE DENSITIES OF WHITE PERCH AT THE BOWLINE POINT PLANT INTAKE, 1979

DATE	AVERAGE TEMPERATURE (DEGREES C)	AVERAGE CONDUCTIVITY (MICROMHOS)	TOTAL VOLUME (CU M)	DAILY AVERAGE DENSITY (NO./1000 CU M)					
				EGGS	YOLK-SAC LARVAE	LARVAE	JUVENILES	UID	TOTAL (EXCLUDING EGGS)
05/21/79	18.1	630.	189.6	0.0	0.0	5.3	0.0	0.0	5.3
05/24/79	18.0	1086.	224.2	0.0	0.0	4.5	0.0	0.0	4.5
05/29/79	18.0	394.	220.7	0.0	0.0	13.6	0.0	0.0	13.6
05/31/79	18.9	184.	249.8	0.0	0.0	4.0	0.0	0.0	4.0
06/04/79	19.9	135.	266.8	0.0	3.7	22.5	0.0	0.0	26.2
06/07/79	21.5	1930.	335.7	0.0	0.0	23.8	0.0	0.0	23.8
06/11/79	21.2	3670.	211.8	0.0	14.2	51.9	0.0	0.0	66.1
06/14/79	21.9	1835.	300.1	0.0	0.0	80.0	0.0	0.0	80.0
06/18/79	23.7	1055.	452.6	0.0	2.2	81.7	0.0	0.0	84.0
06/21/79	24.0	1220.	216.0	0.0	0.0	13.9	0.0	0.0	13.9
06/22/79	23.5	1610.	221.6	0.0	0.0	135.4	0.0	0.0	135.4
06/25/79	22.4	1715.	492.2	0.0	0.0	16.3	0.0	0.0	16.3
06/28/79	23.1	2365.	532.7	0.0	0.0	5.6	0.0	0.0	5.6
07/02/79	23.6	2645.	552.2	0.0	0.0	12.7	1.8	0.0	14.5
07/05/79	22.4	4660.	559.4	0.0	0.0	0.0	3.6	0.0	3.6
07/09/79	23.5	8355.	559.4	0.0	0.0	0.0	0.0	0.0	0.0

TABLE H-4 DAILY AVERAGE DENSITIES OF ATLANTIC TOMCOD AT THE BOWLINE POINT PLANT INTAKE, 1979

				DAILY AVERAGE DENSITY (NO./1000 CU M)					
DATE	AVERAGE TEMPERATURE (DEGREES C)	AVERAGE CONDUCTIVITY (MICROMHOS)	TOTAL VOLUME (CU M)	EGGS	YOLK-SAC LARVAE	LARVAE	JUVENILES	UID	TOTAL (EXCLUDING EGGS)
03/06/79	1.1	129.	455.0	0.0	15.4	2.2	0.0	2.2	19.8
03/13/79	0.8	92.	325.0	0.0	52.3	0.0	0.0	9.2	61.5
03/20/79	3.2	89.	393.5	0.0	129.6	12.7	0.0	10.2	152.5
03/27/79	4.0	108.	429.5	0.0	137.4	21.0	0.0	55.9	214.2

TABLE H-5 DAILY AVERAGE DENSITIES OF CLUPEIDS AT THE BOWLINE POINT PLANT INTAKE, 1979

DATE	AVERAGE TEMPERATURE (DEGREES C)	AVERAGE CONDUCTIVITY (MICROMHOS)	TOTAL VOLUME (CU M)	DAILY AVERAGE DENSITY (NO./1000 CU M) EGGS	YOLK-SAC LARVAE	LARVAE	JUVENILES	UID	TOTAL (EXCLUDING EGGS)
05/21/79	18.1	630.	189.6	0.0	0.0	10.5	0.0	0.0	10.5
05/24/79	18.0	1086.	224.2	0.0	0.0	4.5	0.0	0.0	4.5
05/29/79	18.0	394.	220.7	0.0	0.0	13.6	0.0	0.0	13.6
05/31/79	18.9	184.	249.8	0.0	0.0	24.0	0.0	0.0	24.0
06/04/79	19.9	135.	266.8	0.0	0.0	22.5	0.0	0.0	22.5
06/07/79	21.5	1930.	335.7	0.0	0.0	6.0	0.0	0.0	6.0
06/11/79	21.2	3670.	211.8	0.0	0.0	4.7	0.0	0.0	4.7
06/14/79	21.9	1835.	300.1	0.0	0.0	3.3	0.0	0.0	3.3
06/18/79	23.7	1055.	452.6	0.0	0.0	4.4	0.0	0.0	4.4
06/21/79	24.0	1220.	216.0	0.0	0.0	0.0	0.0	0.0	0.0
06/22/79	23.5	1610.	221.6	0.0	0.0	13.5	0.0	0.0	13.5
06/25/79	22.4	1715.	492.2	0.0	0.0	0.0	0.0	0.0	0.0
06/28/79	23.1	2365.	532.7	0.0	0.0	0.0	0.0	0.0	0.0
07/02/79	23.6	2645.	552.2	0.0	0.0	0.0	0.0	0.0	0.0
07/05/79	22.4	4660.	559.4	0.0	0.0	0.0	0.0	0.0	0.0
07/09/79	23.5	8355.	559.4	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX I

LENGTH DISTRIBUTION OF THE MOST ABUNDANT TAXA COLLECTED DURING ENTRAINMENT ABUNDANCE SAMPLING AT THE BOWLINE POINT PLANT INTAKE, 1979

TABLE I-1 LENGTH-FREQUENCY DISTRIBUTION AND WEEKLY MEAN, RANGE, AND STANDARD DEVIATION OF LENGTHS FOR BAY ANCHOVY IN COLLECTIONS AT THE INTAKE OF THE BOWLINE POINT PLANT, 1979

				LENGTH INTERVALS (MM)									RANGE		
DATE	N	X	SD	0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0 999.9	MIN	MED	MAX
21 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
29 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
4 JUN 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
11 JUN 79	8	3.9	0.6	0	8	0	0	0	0	0	0	0	3.0	4.0	5.0
18 JUN 79	19	7.8	2.2	0	3	8	7	1	0	0	0	0	5.0	8.0	13.0
25 JUN 79	75	8.6	3.0	0	6	42	16	4	7	0	0	0	5.0	8.0	16.0
2 JUL 79	229	11.5	5.0	0	21	56	47	31	28	43	3	0	3.0	11.0	22.0
9 JUL 79	242	8.3	4.9	1	85	79	23	20	18	7	7	2	2.0	6.0	24.0

N=NUMBER OF LENGTHS; MIN=SHORTEST LENGTH
X=MEAN LENGTH; MED=MEDIAN LENGTH
SD=STANDARD DEVIATION; MAX=GREATEST LENGTH
NA=DATA NOT AVAILABLE

TABLE I-2 LENGTH-FREQUENCY DISTRIBUTION AND WEEKLY MEAN, RANGE, AND STANDARD DEVIATION OF LENGTHS FOR STRIPED BASS IN COLLECTIONS AT THE INTAKE OF THE BOWLINE POINT PLANT, 1979

				LENGTH INTERVALS (MM)									RANGE		
DATE	N	X	SD	0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0 999.9	MIN	MED	MAX
21 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
29 MAY 79	4	7.5	0.5	0	0	4	0	0	0	0	0	0	7.0	7.5	8.0
4 JUN 79	9	7.7	1.2	0	0	7	2	0	0	0	0	0	6.0	7.0	10.0
11 JUN 79	27	7.2	1.1	0	2	22	3	0	0	0	0	0	5.0	7.0	9.0
18 JUN 79	35	8.5	2.9	0	0	24	5	4	2	0	0	0	6.0	7.0	17.0
25 JUN 79	1	11.0	0.0	0	0	0	1	0	0	0	0	0	11.0	11.0	11.0
2 JUL 79	3	12.3	2.1	0	0	0	1	1	1	0	0	0	10.0	12.0	15.0
9 JUL 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0

N=NUMBER OF LENGTHS; MIN=SHORTEST LENGTH
X=MEAN LENGTH; MED=MEDIAN LENGTH
SD=STANDARD DEVIATION; MAX=GREATEST LENGTH
NA=DATA NOT AVAILABLE

TABLE I-3 LENGTH-FREQUENCY DISTRIBUTION AND WEEKLY MEAN, RANGE, AND STANDARD DEVIATION OF LENGTHS FOR WHITE PERCH IN COLLECTIONS AT THE INTAKE OF THE BOWLINE POINT PLANT, 1979

DATE	N	X	SD	LENGTH INTERVALS (MM) 0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0 999.9	RANGE MIN	MED	MAX
21 MAY 79	2	4.5	0.5	0	2	0	0	0	0	0	0	0	4.0	4.5	5.0
29 MAY 79	4	5.3	1.1	0	3	1	0	0	0	0	0	0	4.0	5.0	7.0
4 JUN 79	15	4.4	1.0	1	13	1	0	0	0	0	0	0	2.0	5.0	6.0
11 JUN 79	38	5.4	1.1	0	26	12	0	0	0	0	0	0	4.0	5.0	8.0
18 JUN 79	69	7.4	2.1	0	17	29	22	1	0	0	0	0	3.0	8.0	12.0
25 JUN 79	11	7.8	2.7	0	3	3	4	1	0	0	0	0	5.0	6.0	13.0
2 JUL 79	10	11.0	2.0	0	0	1	6	2	1	0	0	0	8.0	10.0	15.0
9 JUL 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0

N=NUMBER OF LENGTHS; MIN=SHORTEST LENGTH
X=MEAN LENGTH; MED=MEDIAN LENGTH
SD=STANDARD DEVIATION; MAX=GREATEST LENGTH
NA=DATA NOT AVAILABLE

TABLE I-4 LENGTH-FREQUENCY DISTRIBUTION AND WEEKLY MEAN, RANGE, AND STANDARD DEVIATION OF LENGTHS FOR ATLANTIC TOMCOD IN COLLECTIONS AT THE INTAKE OF THE BOWLINE POINT PLANT, 1979

				LENGTH INTERVALS (MM)									RANGE		
DATE	N	X	SD	0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0 999.9	MIN	MED	MAX
6 MAR 79	7	7.1	0.3	0	0	7	0	0	0	0	0	0	7.0	7.0	8.0
13 MAR 79	18	7.0	0.3	0	0	18	0	0	0	0	0	0	6.0	7.0	8.0
20 MAR 79	53	7.0	0.3	0	0	53	0	0	0	0	0	0	6.0	7.0	8.0
27 MAR 79	63	7.0	0.3	0	0	63	0	0	0	0	0	0	6.0	7.0	8.0

N=NUMBER OF LENGTHS; MIN=SHORTEST LENGTH
X=MEAN LENGTH; MED=MEDIAN LENGTH
SD=STANDARD DEVIATION; MAX=GREATEST LENGTH
NA=DATA NOT AVAILABLE

TABLE I-5 LENGTH-FREQUENCY DISTRIBUTION AND WEEKLY MEAN, RANGE, AND STANDARD DEVIATION OF LENGTHS FOR CLUPEIDS IN COLLECTIONS AT THE INTAKE OF THE BOWLINE POINT PLANT, 1979

				LENGTH INTERVALS (MM)									RANGE		
DATE	N	X	SD	0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0 999.9	MIN	MED	MAX
21 MAY 79	3	7.3	1.2	0	0	2	1	0	0	0	0	0	6.0	7.0	9.0
29 MAY 79	8	8.3	1.5	0	0	5	3	0	0	0	0	0	7.0	7.5	11.0
4 JUN 79	8	9.0	2.5	0	0	4	3	0	1	0	0	0	6.0	8.5	15.0
11 JUN 79	2	8.0	1.0	0	0	1	1	0	0	0	0	0	7.0	8.0	9.0
18 JUN 79	5	16.0	3.8	0	0	0	0	2	1	1	1	0	12.0	16.0	22.0
25 JUN 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
2 JUL 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
9 JUL 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0

N=NUMBER OF LENGTHS;	MIN=SHORTEST LENGTH
X=MEAN LENGTH;	MED=MEDIAN LENGTH
SD=STANDARD DEVIATION;	MAX=GREATEST LENGTH
NA=DATA NOT AVAILABLE	

APPENDIX J

LENGTH-FREQUENCY DATA FOR ENTRAINMENT SURVIVAL STUDIES SUMMARIZED BY SAMPLING WEEK AT THE BOWLINE POINT PLANT, 1979

TABLE J-1 LENGTH-FREQUENCY DISTRIBUTION OF STRIPED BASS COLLECTED BY SAMPLING WEEK AT THE INTAKE, DISCHARGE, AND DIFFUSER OF THE BOWLINE POINT PLANT DURING 1979 ENTRAINMENT SURVIVAL STUDIES

				LENGTH INTERVALS (MM)									RANGE		
DATE	N	X	SD	0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0+	MIN	MED	MAX
Intake--pumpless sampling flume															
30 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
4 JUN 79	6	6.7	0.9	0	0	6	0	0	0	0	0	0	6.0	6.0	8.0
11 JUN 79	24	6.9	1.1	0	1	21	2	0	0	0	0	0	5.0	7.0	10.0
18 JUN 79	17	7.2	1.6	0	2	9	6	0	0	0	0	0	5.0	6.0	10.0
25 JUN 79	1	7.0	0.0	0	0	1	0	0	0	0	0	0	7.0	7.0	7.0
Intake--pumped larval table															
23 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 MAY 79	1	6.0	0.0	0	0	1	0	0	0	0	0	0	6.0	6.0	6.0
4 JUN 79	3	5.7	0.5	0	1	2	0	0	0	0	0	0	5.0	6.0	6.0
11 JUN 79	21	6.8	1.2	0	1	19	1	0	0	0	0	0	5.0	6.0	10.0
18 JUN 79	6	8.2	3.2	0	1	3	0	2	0	0	0	0	4.0	7.0	13.0
25 JUN 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
Discharge (Unit 1)															
23 MAY 79	1	7.0	0.0	0	0	1	0	0	0	0	0	0	7.0	7.0	7.0
30 MAY 79	5	7.0	0.9	0	0	5	0	0	0	0	0	0	6.0	7.0	8.0
4 JUN 79	23	6.6	1.1	0	3	18	2	0	0	0	0	0	5.0	6.0	9.0
11 JUN 79	35	6.8	1.4	0	4	26	5	0	0	0	0	0	5.0	6.0	10.0
18 JUN 79	48	8.4	1.8	0	4	20	22	2	0	0	0	0	5.0	8.5	12.0
25 JUN 79	2	11.5	1.5	0	0	0	1	1	0	0	0	0	10.0	11.5	13.0
Diffuser (Unit 1)															
23 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 MAY 79	1	8.0	0.0	0	0	1	0	0	0	0	0	0	8.0	8.0	8.0
4 JUN 79	10	7.0	1.4	0	0	8	2	0	0	0	0	0	6.0	6.0	10.0
11 JUN 79	21	6.7	1.0	0	1	18	2	0	0	0	0	0	5.0	6.0	9.0
18 JUN 79	28	8.0	1.8	0	1	16	10	1	0	0	0	0	5.0	7.5	12.0
25 JUN 79	1	11.0	0.0	0	0	0	1	0	0	0	0	0	11.0	11.0	11.0

N=NUMBER OF LENGTHS; MIN=SHORTEST LENGTH
X=MEAN LENGTH; MED=MEDIAN LENGTH
SD=STANDARD DEVIATION; MAX=GREATEST LENGTH
NA=DATA NOT AVAILABLE

TABLE J-2 LENGTH-FREQUENCY DISTRIBUTION OF WHITE PERCH COLLECTED BY SAMPLING WEEK AT THE INTAKE, DISCHARGE, AND DIFFUSER OF THE BOWLINE POINT PLANT DURING 1979 ENTRAINMENT SURVIVAL STUDIES

				LENGTH INTERVALS (MM)									RANGE		
DATE	N	X	SD	0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0+	MIN	MED	MAX
Intake--pumpless sampling flume															
30 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
4 JUN 79	13	4.9	1.1	0	10	3	0	0	0	0	0	0	4.0	5.0	8.0
11 JUN 79	36	4.8	1.4	0	29	5	2	0	0	0	0	0	3.0	4.0	9.0
18 JUN 79	24	5.8	2.5	0	13	9	1	1	0	0	0	0	3.0	4.5	12.0
25 JUN 79	1	4.0	0.0	0	1	0	0	0	0	0	.0	0	4.0	4.0	4.0
Intake--pumped larval table															
23 MAY 79	1	4.0	0.0	0	1	0	0	0	0	0	0	0	4.0	4.0	4.0
30 MAY 79	2	3.5	0.5	0	2	0	0	0	0	0	0	0	3.0	3.5	4.0
4 JUN 79	14	4.3	0.6	0	14	0	0	0	0	0	0	0	3.0	4.0	5.0
11 JUN 79	81	4.6	0.9	0	69	12	0	0	0	0	0	0	3.0	4.0	8.0
18 JUN 79	32	5.0	1.9	0	22	7	3	0	0	0	0	0	3.0	4.5	9.0
25 JUN 79	1	4.0	0.0	0	1	0	0	0	0	0	0	0	4.0	4.0	4.0
Discharge (Unit 1)															
23 MAY 79	1	4.0	0.0	0	1	0	0	0	0	0	0	0	4.0	4.0	4.0
30 MAY 79	3	4.0	0.8	0	3	0	0	0	0	0	0	0	3.0	4.0	5.0
4 JUN 79	30	4.7	0.7	0	28	2	0	0	0	0	0	0	3.0	4.0	6.0
11 JUN 79	54	4.9	1.6	0	42	8	4	0	0	0	0	0	3.0	4.0	10.0
18 JUN 79	34	4.6	1.8	0	28	3	3	0	0	0	0	0	3.0	4.0	10.0
25 JUN 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
Diffuser (Unit 1)															
23 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 MAY 79	3	4.0	0.8	0	3	0	0	0	0	0	0	0	3.0	4.0	5.0
4 JUN 79	15	4.3	0.7	0	14	1	0	0	0	0	0	0	3.0	4.0	6.0
11 JUN 79	60	4.5	1.3	0	50	9	1	0	0	0	0	0	3.0	4.0	10.0
18 JUN 79	18	4.2	1.0	0	16	2	0	0	0	0	0	0	3.0	4.0	7.0
25 JUN 79	1	4.0	0.0	0	1	0	0	0	0	0	0	0	4.0	4.0	4.0

N=NUMBER OF LENGTHS; MIN=SHORTEST LENGTH
X=MEAN LENGTH; MED=MEDIAN LENGTH
SD=STANDARD DEVIATION; MAX=GREATEST LENGTH
NA=DATA NOT AVAILABLE

TABLE J-3 LENGTH-FREQUENCY DISTRIBUTION OF BAY ANCHOVY COLLECTED BY SAMPLING WEEK AT THE INTAKE, DISCHARGE, AND DIFFUSER OF THE BOWLINE POINT PLANT DURING 1979 ENTRAINMENT SURVIVAL STUDIES

				LENGTH INTERVALS (MM)									RANGE		
DATE	N	X	SD	0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0+	MIN	MED	MAX
Intake--pumpless sampling flume															
30 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
4 JUN 79	2	4.0	0.0	0	2	0	0	0	0	0	0	0	4.0	4.0	4.0
11 JUN 79	9	5.3	1.4	0	5	4	0	0	0	0	0	0	3.0	5.0	7.0
18 JUN 79	3	9.0	2.2	0	0	2	0	1	0	0	0	0	7.0	8.0	12.0
25 JUN 79	20	7.9	2.9	0	4	11	2	2	1	0	0	0	4.0	7.0	16.0
Intake--pumped larval table															
23 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
4 JUN 79	2	4.0	0.0	0	2	0	0	0	0	0	0	0	4.0	4.0	4.0
11 JUN 79	54	5.3	1.4	0	30	23	1	0	0	0	0	0	3.0	5.0	9.0
18 JUN 79	2	7.0	1.0	0	0	2	0	0	0	0	0	0	6.0	7.0	8.0
25 JUN 79	71	7.9	3.2	0	20	27	12	9	3	0	0	0	4.0	7.0	16.0
Discharge (Unit 1)															
23 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
4 JUN 79	1	3.0	0.0	0	1	0	0	0	0	0	0	0	3.0	3.0	3.0
11 JUN 79	12	5.2	0.9	0	8	4	0	0	0	0	0	0	4.0	5.0	7.0
18 JUN 79	1	5.0	0.0	0	1	0	0	0	0	0	0	0	5.0	5.0	5.0
25 JUN 79	29	7.8	3.3	0	9	11	5	2	2	0	0	0	4.0	7.0	16.0
Diffuser (Unit 1)															
23 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
4 JUN 79	1	4.0	0.0	0	1	0	0	0	0	0	0	0	4.0	4.0	4.0
11 JUN 79	12	4.9	1.0	0	7	5	0	0	0	0	0	0	3.0	5.0	6.0
18 JUN 79	3	8.7	1.9	0	0	1	2	0	0	0	0	0	6.0	10.0	10.0
25 JUN 79	20	8.1	3.2	0	5	8	3	3	1	0	0	0	4.0	7.0	15.0

N=NUMBER OF LENGTHS; MIN=SHORTEST LENGTH
X=MEAN LENGTH; MED=MEDIAN LENGTH
SD=STANDARD DEVIATION; MAX=GREATEST LENGTH
NA=DATA NOT AVAILABLE

TABLE J-4 LENGTH-FREQUENCY DISTRIBUTION OF CLUPEIDS COLLECTED BY SAMPLING WEEK AT THE INTAKE, DISCHARGE, AND DIFFUSER OF THE BOWLINE POINT PLANT DURING 1979 ENTRAINMENT SURVIVAL STUDIES

				LENGTH INTERVALS (MM)									RANGE		
DATE	N	X	SD	0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0+	MIN	MED	MAX
Intake--pumpless sampling flume															
30 MAY 79	2	6.0	0.0	0	0	2	0	0	0	0	0	0	6.0	6.0	6.0
4 JUN 79	10	9.5	5.2	0	1	5	3	0	0	0	0	1	4.0	8.0	24.0
11 JUN 79	3	10.7	2.1	0	0	1	1	1	0	0	0	0	8.0	11.0	13.0
18 JUN 79	2	20.5	0.5	0	0	0	0	0	0	1	1	0	20.0	20.5	21.0
25 JUN 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
Intake--pumped larval table															
23 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 MAY 79	11	6.1	0.9	0	3	8	0	0	0	0	0	0	5.0	6.0	8.0
4 JUN 79	21	8.0	1.2	0	0	14	7	0	0	0	0	0	6.0	8.0	11.0
11 JUN 79	11	9.5	3.8	0	0	6	4	0	0	0	1	0	6.0	8.0	21.0
18 JUN 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
25 JUN 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
Discharge (Unit 1)															
23 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 MAY 79	22	6.6	1.5	0	4	16	2	0	0	0	0	0	5.0	6.0	11.0
4 JUN 79	10	7.4	1.0	0	1	8	1	0	0	0	0	0	5.0	7.5	9.0
11 JUN 79	10	10.8	2.3	0	0	2	5	2	1	0	0	0	8.0	10.5	16.0
18 JUN 79	4	15.3	2.2	0	0	0	0	1	2	1	0	0	12.0	15.5	18.0
25 JUN 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
Diffuser (Unit 1)															
23 MAY 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 MAY 79	15	6.7	1.8	0	0	14	0	1	0	0	0	0	6.0	6.0	13.0
4 JUN 79	21	8.9	4.6	0	0	15	3	1	0	1	0	1	6.0	7.0	25.0
11 JUN 79	2	10.0	2.0	0	0	1	0	1	0	0	0	0	8.0	10.0	12.0
18 JUN 79	2	15.5	2.5	0	0	0	0	1	0	1	0	0	13.0	15.5	18.0
25 JUN 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0

N=NUMBER OF LENGTHS; MIN=SHORTEST LENGTH
X=MEAN LENGTH; MED=MEDIAN LENGTH
SD=STANDARD DEVIATION; MAX=GREATEST LENGTH
NA=DATA NOT AVAILABLE

APPENDIX K

NORMALIZED EXTENDED SURVIVAL OF ICHTHYOPLANKTON ENTRAINED AT THE BOWLINE POINT PLANT, 1979

TABLE K-1 EXTENDED SURVIVAL OF ALIVE (LIVE + STUNNED) LARVAL AND JUVENILE FISHES COLLECTED AT THE INTAKE, DISCHARGE, AND DIFFUSER DURING ENTRAINMENT SURVIVAL SAMPLING AT THE BOWLINE POINT PLANT, 1979

				Hours							
Species	Life Stage	Station[(a)]	Number of Organisms	0	3	6	12	24	48	72	96
Striped bass	Yolk-sac larvae	I_1P	5	1.000	1.000	1.000	1.000	1.000	0.600±0.219[(b)]	0.400±0.219	0.400±0.219
		I_1R	7	1.000	1.000	1.000	0.857±0.132	0.857±0.132	0.857±0.132	0.857±0.132	0.714±0.171
		D_1P	12	1.000	0.917±0.080	0.917±0.080	0.833±0.108	0.833±0.108	0.750±0.125	0.583±0.142	0.333±0.136
		D_1D	7	1.000	0.857±0.132	0.714±0.171	0.571±0.187	0.571±0.187	0.429±0.187	0.286±0.171	0.286±0.171
	Post yolk-sac larvae	I_1P	22	1.000	1.000	0.955±0.044	0.909±0.061	0.864±0.073	0.818±0.082	0.773±0.089	0.682±0.099
		I_1R	29	1.000	0.931±0.047	0.897±0.057	0.793±0.075	0.793±0.075	0.759±0.079	0.759±0.079	0.690±0.086
		D_1P	43	1.000	0.884±0.049	0.744±0.067	0.651±0.073	0.605±0.075	0.558±0.076	0.488±0.076	0.488±0.076
		D_1D	18	1.000	0.611±0.115	0.500±0.118	0.333±0.111	0.333±0.111	0.333±0.111	0.278±0.106	0.222±0.098
	Juveniles	I_1P	0	--	--	--	--	--	--	--	--
		I_1R	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
		D_1P	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
		D_1D	0	--	--	--	--	--	--	--	--
White perch	Yolk-sac larvae	I_1P	0	--	--	--	--	--	--	--	--
		I_1R	1	1.000	1.000	1.000	1.000	1.000	0	0	0
		D_1P	1	1.000	1.000	1.000	0	0	0	0	0
		D_1D	7	1.000	0.857±0.132	0.571±0.187	0.286±0.171	0.143±0.132	0	0	0
	Post yolk-sac larvae	I_1P	86	1.000	0.837±0.040	0.814±0.042	0.721±0.048	0.616±0.052	0.581±0.053	0.430±0.053	0.326±0.051
		I_1R	27	1.000	0.815±0.075	0.778±0.080	0.704±0.088	0.704±0.088	0.630±0.093	0.593±0.095	0.407±0.095
		D_1P	29	1.000	0.828±0.070	0.724±0.083	0.517±0.093	0.448±0.092	0.448±0.092	0.379±0.090	0.207±0.075
		D_1D	28	1.000	0.714±0.085	0.429±0.094	0.393±0.092	0.357±0.091	0.357±0.091	0.286±0.085	0.214±0.078
Clupeids[(c)]	Post yolk-sac larvae	I_1P	24	1.000	0.500±0.102	0.167±0.076	0.083±0.056	0.042±0.041	0.042±0.041	0.042±0.041	0.042±0.041
		I_1R	11	1.000	0.545±0.150	0.364±0.145	0.091±0.087	0	0	0	0
		D_1P	16	1.000	0.500±0.125	0.063±0.061	0	0	0	0	0
		D_1D	12	1.000	0.667±0.136	0.500±0.144	0.167±0.108	0.083±0.080	0.083±0.080	0.083±0.080	0.083±0.080

(a) I_1P = intake, Unit 1, pumped-larval table; I_1R = intake, Unit 1, rear-draw plankton sampling flume; D_1P = discharge, Unit 1, pumped-larval table; D_1D = discharge, Unit 1, pumpless-plankton sampling flume.

(b) ±1 standard error.

(c) Includes all organisms in the family Clupeidae.

TABLE K-2 EXTENDED SURVIVAL OF LIVE LARVAL AND JUVENILE FISHES COLLECTED AT THE INTAKE, DISCHARGE, AND DIFFUSER DURING ENTRAINMENT SURVIVAL SAMPLING AT THE BOWLINE POINT PLANT, 1979

Species	Life Stage	Station[a]	Number of Organisms	Hours 0	3	6	12	24	48	72	96
Striped bass	Yolk-sac larvae	I_1P	5	1.000	1.000	1.000	1.000	1.000	0.600±0.219[b]	0.400±0.219	0.400±0.219
		I_1R	7	1.000	1.000	1.000	0.857±0.132	0.857±0.132	0.857±0.132	0.857±0.132	0.714±0.171
		D_1P	12	1.000	0.917±0.080	0.917±0.080	0.833±0.108	0.833±0.108	0.750±0.125	0.583±0.142	0.333±0.136
		D_1D	6	1.000	1.000	0.833±0.152	0.667±0.192	0.667±0.192	0.500±0.204	0.333±0.192	0.333±0.192
	Post yolk-sac larvae	I_1P	21	1.000	1.000	0.952±0.046	0.905±0.064	0.857±0.076	0.810±0.086	0.762±0.093	0.667±0.103
		I_1R	27	1.000	1.000	0.963±0.036	0.852±0.068	0.852±0.068	0.815±0.075	0.815±0.075	0.741±0.084
		D_1P	32	1.000	0.938±0.043	0.844±0.064	0.750±0.077	0.719±0.079	0.656±0.084	0.625±0.086	0.625±0.086
		D_1D	15	1.000	0.733±0.114	0.600±0.126	0.400±0.126	0.400±0.126	0.400±0.126	0.333±0.122	0.267±0.114
	Juveniles	I_1P	0	--	-	--	--	--	--	--	--
		I_1R	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
		D_1P	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
		D_1D	0	--	--	--	--	--	--	--	--
White perch	Yolk-sac larvae	I_1P	0	--	--	--	--	--	--	--	--
		I_1R	1	1.000	1.000	1.000	1.000	1.000	0	0	0
		D_1P	0	--	--	--	--	--	--	--	--
		D_1D	4	1.000	1.000	0.750±0.217	0.500±0.250	0.250±0.217	0	0	0
	Post yolk-sac larvae	I_1P	74	1.000	0.932±0.029	0.919±0.032	0.824±0.044	0.716±0.052	0.676±0.054	0.500±0.058	0.378±0.056
		I_1R	23	1.000	0.913±0.059	0.870±0.070	0.826±0.079	0.826±0.079	0.739±0.092	0.696±0.096	0.478±0.104
		D_1P	22	1.000	0.955±0.044	0.818±0.082	0.636±0.103	0.545±0.106	0.545±0.106	0.455±0.106	0.227±0.089
		D_1D	19	1.000	0.895±0.070	0.579±0.113	0.526±0.115	0.474±0.115	0.474±0.115	0.421±0.113	0.316±0.107
Clupeids[c]	Post yolk-sac larvae	I_1P	15	1.000	0.667±0.122	0.267±0.114	0.133±0.088	0.067±0.065	0.067±0.065	0.067±0.065	0.067±0.065
		I_1R	9	1.000	0.556±0.166	0.333±0.157	0.111±0.105	0	0	0	0
		D_1P	9	1.000	0.667±0.157	0.111±0.105	0	0	0	0	0
		D_1D	9	1.000	0.778±0.139	0.667±0.157	0.222±0.139	0.111±0.105	0.111±0.105	0.111±0.105	0.111±0.105

(a) I1P = intake, Unit 1, pumped-larval table; I_1R = intake, Unit 1, rear-draw plankton sampling flume; D_1P = discharge, Unit 1, pumped-larval table; D_1D = discharge, Unit 1, pumpless-plankton sampling flume.

(b) ±1 standard error.

(c) Includes all organisms in the family Clupeidae.

TABLE K-3 EXTENDED SURVIVAL OF STUNNED LARVAL FISHES COLLECTED AT THE INTAKE, DISCHARGE, AND DIFFUSER DURING ENTRAINMENT SURVIVAL SAMPLING AT THE BOWLINE POINT PLANT, 1979

Species	Life Stage	Station(a)	Number of Organisms	Hours							
				0	3	6	12	24	48	72	96
Striped bass	Yolk-sac larvae	I_1P	0	--	--	--	--	--	--	--	--
		I_1R	0	--	--	--	--	--	--	--	--
		D_1P	0	--	--	--	--	--	--	--	--
		D_1D	1	1.000	0	0	0	0	0	0	0
	Post yolk-sac larvae	I_1P	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
		I_1R	2	1.000	0	0	0	0	0	0	0
		D_1P	11	1.000	0.727±0.134(b)	0.455±0.150	0.364±0.145	0.273±0.134	0.273±0.134	0.091±0.087	0.091±0.087
		D_1D	3	1.000	0	0	0	0	0	0	0
White perch	Yolk-sac larvae	I_1P	0	--	--	--	--	--	--	--	--
		I_1R	0	--	--	--	--	--	--	--	--
		D_1P	1	1.000	1.000	1.000	0	0	0	0	0
		D_1D	3	1.000	0.667±0.272	0.333±0.272	0	0	0	0	0
	Post yolk-sac larvae	I_1P	12	1.000	0.250±0.125	0.167±0.108	0.083±0.080	0	0	0	0
		I_1R	4	1.000	0.250±0.217	0.250±0.217	0	0	0	0	0
		D_1P	7	1.000	0.429±0.187	0.429±0.187	0.143±0.132	0.143±0.132	0.143±0.132	0.143±0.132	0.143±0.132
		D_1D	9	1.000	0.333±0.157	0.111±0.105	0.111±0.105	0.111±0.105	0.111±0.105	0	0
Clupeids(c)	Post yolk-sac larvae	I_1P	9	1.000	0.222±0.139	0	0	0	0	0	0
		I_1R	2	1.000	0.500±0.354	0.500±0.354	0	0	0	0	0
		D_1P	7	1.000	0.286±0.171	0	0	0	0	0	0
		D_1D	3	1.000	0.333±0.272	0	0	0	0	0	0

(a) I_1P = intake, Unit 1, pumped-larval table; I_1R = intake, Unit 1, rear-draw plankton sampling flume; D_1P = discharge, Unit 1, pumped-larval table; D_1D = discharge, Unit 1, pumpless-plankton sampling flume.

(b) ±1 standard error.

(c) Includes all organisms in the family Clupeidae.

TABLE K-4 SURVIVAL OF ICHTHYOPLANKTON HELD FOR 14 DAYS FOLLOWING ENTRAINMENT AT THE BOWLINE POINT PLANT, 1979

	Proportion Surviving(a)											
	Striped Bass				White Perch				Clupeidae	Bay Anchovy	Killifish	Tesselated Darter
Observation	I_1P(b) (n=6)	D_1P (n=7)	I_1R (n=7)	D_1D (n=1)	I_1P (n=14)	D_1P (n=3)	I_1R (n=6)	D_1D (n=1)	I_1P (n=1)	I_1R (n=24)	D_1P (n=1)	D_1D (n=1)
Initial	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3 hr	1.00	1.00	1.00	1.00	0.86±0.09	1.00	1.00	1.00	1.00	0.79±0.08	1.00	1.00
6 hr	0.83±0.15(c)	1.00	1.00	1.00	0.86±0.09	1.00	1.00	1.00	1.00	0.50±0.10	1.00	1.00
12 hr	0.83±0.15	1.00	1.00	1.00	0.71±0.12	1.00	1.00	1.00	1.00	0.50±0.10	1.00	1.00
24 hr	0.83±0.15	1.00	1.00	1.00	0.64±0.13	1.00	1.00	1.00	1.00	0.42±0.10	1.00	1.00
48 hr	0.83±0.15	1.00	1.00	1.00	0.64±0.13	1.00	1.00	1.00	1.00	0.33±0.10	1.00	1.00
72 hr	0.83±0.15	1.00	1.00	1.00	0.50±0.13	1.00	1.00	1.00	1.00	0.25±0.09	1.00	1.00
96 hr	0.83±0.15	1.00	0.86±0.13	1.00	0.43±0.13	0.67±0.27	0.67±0.19	1.00	1.00	0.21±0.08	1.00	1.00
5 day	0.83±0.15	0.86±0.13	0.86±0.13	1.00	0.29±0.12	0.33±0.27	0.50±0.20	0.00	1.00	0.17±0.08	1.00	1.00
6 day	0.83±0.15	0.71±0.17	0.57±0.19	1.00	0.29±0.12	0.33±0.27	0.50±0.20	0.00	1.00	0.17±0.08	1.00	1.00
7 day	0.83±0.15	0.71±0.17	0.57±0.19	1.00	0.29±0.12	0.33±0.27	0.50±0.20	0.00	0.00	0.13±0.07	1.00	1.00
8 day	0.83±0.15	0.71±0.17	0.43±0.19	1.00	0.29±0.12	0.33±0.27	0.50±0.20	0.00	0.00	0.13±0.07	1.00	1.00
9 day	0.83±0.15	0.71±0.17	0.43±0.19	1.00	0.29±0.12	0.33±0.27	0.50±0.20	0.00	0.00	0.13±0.07	1.00	1.00
10 day	0.83±0.15	0.71±0.17	0.43±0.19	1.00	0.29±0.12	0.33±0.27	0.33±0.19	0.00	0.00	0.08±0.06	1.00	1.00
11 day	0.83±0.15	0.71±0.17	0.43±0.19	1.00	0.21±0.11	0.33±0.27	0.33±0.19	0.00	0.00	0.08±0.06	1.00	1.00
12 day	0.83±0.15	0.57±0.19	0.43±0.19	1.00	0.21±0.11	0.33±0.27	0.33±0.19	0.00	0.00	0.08±0.06	1.00	1.00
13 day	0.83±0.15	0.57±0.19	0.43±0.19	1.00	0.21±0.11	0.33±0.27	0.33±0.19	0.00	0.00	0.04±0.04	1.00	1.00
14 day	0.83±0.15	0.57±0.19	0.43±0.19	1.00	0.14±0.09	0.33±0.27	0.33±0.19	0.00	0.00	0.04±0.04(d)	1.00	1.00

(a) Includes all life stages.

(b) I_1P = pumped larval table (intake); D_1P = pumped larval table (discharge); I_1R = pumpless plankton sampling flume (intake); D_1D = pumpless plankton sampling flume (diffuser).

(c) ± standard error.

(d) Special bay anchovy study conducted at Bowline Intake from 23 July to 13 August; surviving anchovy larvae were held for 99 days following collection.

APPENDIX L

SUMMARY OF SURVIVAL OF HATCHERY-REARED STRIPED BASS BY SAMPLE DATE FOR DIRECT RELEASE STUDIES CONDUCTED AT THE BOWLINE POINT PLANT, 1979

TABLE L-1 SUMMARY OF SURVIVAL DATA FOR HATCHERY-REARED STRIPED BASS BY SAMPLE DATE FOR DIRECT RELEASE STUDIES CONDUCTED AT THE BOWLINE POINT PLANT, 1979

Release Date	Life Stage/Age	Station/Sample Type	Pump Operation	Temp. (C)	No. of Fish	Proportion Alive(a) Initial	Proportion Alive(a) 24-Hour	Proportion Alive(a) 96-Hour	Prop. Released Dead	Adjusted Proportion Alive Initial	Adjusted Proportion Alive 24-Hour	Adjusted Proportion Alive 96-Hour
21 MAY	Eggs/1 day since ovulation	Holding controls	2-full	19.0	43	1.000±0.000	1.000±0.000	1.000±0.000	--			
		Intake--pump injected controls		20.0	47	0.553±0.073	0.277±0.065	0.277±0.065				
		Intake--pumpless injected controls		20.0	16	1.000±0.000	1.000±0.000	1.000±0.000				
		Discharge standpipe		19.0	27	0.444±0.096	0.222±0.080	0.222±0.080				
		Discharge diffuser		--	--	--	--	--				
22 MAY	Eggs/3 days since ovulation	Holding controls	2-full	21.0	46	1.000±0.000	0.978±0.022	0.978±0.022	--			
		Intake--pump injected controls		21.0	36	0.833±0.039	0.833±0.039	0.833±0.039				
		Intake--pumpless injected controls		--	--	--	--	--				
		Discharge standpipe		19.0	6	0.500±0.204	0.500±0.204	0.500±0.204				
		Discharge diffuser		19.0	8	0.750±0.153	0.750±0.153	0.750±0.153				
24 MAY	Eggs/2 days since ovulation	Holding controls	2-full	19.0	33	1.000±0.000	0.970±0.030	0.909±0.050	--			
		Intake--pump injected controls		19.0	63	0.810±0.049	0.714±0.057	0.683±0.059				
		Intake--pumpless injected controls		19.0	143	0.944±0.019	0.902±0.025	0.811±0.033				
		Discharge standpipe		19.0	11	0.000± --	0.000± --	0.000± --				
		Discharge diffuser		18.0	19	0.789±0.094	0.789±0.094	0.737±0.101				
24 MAY	Yolk-sac larvae/ 5 days	Holding controls	2-full	19.0	43	1.000±0.000	0.721±0.068	0.349±0.073	0.02			
		Intake--pump injected controls		19.0	109	0.220±0.040	0.119±0.031	0.073±0.025				
		Intake--pumpless injected controls		19.0	136	0.140±0.030	0.103±0.026	0.059±0.020				
		Discharge standpipe		19.0	30	0.300±0.084	0.267±0.081	0.067±0.046	(29.40)	0.306±0.085	0.272±0.082	0.068±0.048
		Discharge diffuser		18.0	15	0.267±0.114	0.200±0.103	0.067±0.065	(14.70)	0.272±0.116	0.204±0.105	0.068±0.066
25 MAY	Yolk-sac larvae/ 3 days	Holding controls	2-full	19.0	46	1.000±0.000	1.000±0.000	0.717±0.066	0.02			
		Intake--pump injected controls		18.0	34	0.382±0.083	0.324±0.080	0.235±0.073				
		Intake--pumpless injected controls		18.0	24	0.208±0.083	0.208±0.083	0.125±0.068				
		Discharge standpipe		19.0	44	0.227±0.063	0.159±0.055	0.159±0.055	(43.12)	0.231±0.064	0.162±0.056	0.162±0.056
		Discharge diffuser		18.0	22	0.273±0.095	0.227±0.089	0.000± --	(21.56)	0.278±0.096	0.232±0.091	0.000± --
29 MAY	Yolk-sac larvae/ 4 days	Holding controls	2-full	19.0	41	1.000±0.000	0.561±0.078	0.317±0.073	0.07			
		Intake--pump injected controls		19.0	50	0.480±0.071	0.200±0.057	0.180±0.054				
		Intake--pump gear controls		19.0	46	0.543±0.073	0.283±0.066	0.109±0.046				
		Intake--pumpless injected controls		20.0	52	0.269±0.061	0.173±0.052	0.058±0.032				
		Intake--pumpless gear controls		--	--	--	--	--				

TABLE L-1 (CONT.)

Release Date	Life Stage/Age	Station/Sample Type	Pump Operation	Temp. (C)	No. of Fish	Proportion Alive(a)			Prop. Released Dead	Adjusted Proportion Alive		
						Initial	24-Hour	96-Hour		Initial	24-Hour	96-Hour
29 MAY (cont.)		Discharge standpipe		19.0	26	0.500±0.098	0.346±0.093	0.038±0.037	24.18	0.538±0.101	0.372±0.098	0.041±0.040
		Discharge standpipe gear control		19.0	31	0.677±0.084	0.613±0.087	0.484±0.090				
		Discharge diffuser		18.0	8	0.375±0.171	0.250±0.153	0.250±0.153	(7.44)	0.403±0.180	0.269±0.163	0.269±0.163
		Discharge diffuser gear control		19.0	22	0.636±0.103	0.409±0.105	0.182±0.082				
31 MAY	Post-yolk-sac larvae/9 days	Holding controls	2-full	20.0	49	1.000±0.000	0.143±0.050	0.061±0.034	0.09			
		Intake--pump injected controls		20.0	38	0.263±0.071	0.184±0.063	0.132±0.055				
		Intake--pump gear controls		20.0	20	0.750±0.097	0.400±0.110	0.350±0.107				
		Intake--pumpless injected controls		21.0	55	0.582±0.067	0.200±0.054	0.182±0.052				
		Intake--pumpless gear control		20.0	21	0.762±0.093	0.619±0.106	0.429±0.108				
		Discharge standpipe		20.0	59	0.458±0.065	0.339±0.062	0.254±0.057	(53.69)	0.503±0.068	0.373±0.066	0.279±0.061
		Discharge standpipe gear control		20.0	23	0.522±0.104	0.478±0.104	0.391±0.102				
		Discharge diffuser		20.0	26	0.308±0.091	0.192±0.077	0.154±0.071	(23.66)	0.338±0.097	0.211±0.084	0.169±0.077
		Discharge diffuser gear control		19.0	27	0.296±0.088	0.111±0.060	0.111±0.060				
5 JUN	Post-yolk-sac larvae/7 and 14 days	Holding controls	2-full (Unit 2)	22.0	49	1.000±0.000	0.796±0.058	0.694±0.066	0.06			
		Intake--pump injected controls		22.0	44	0.341±0.071	0.205±0.061	0.182±0.058				
		Intake--pump gear control		21.0	26	0.731±0.087	0.423±0.097	0.308±0.028				
		Intake--pumpless injected controls		22.0	45	0.467±0.074	0.333±0.070	0.333±0.070				
		Intake--pumpless gear control		22.0	25	0.320±0.093	0.280±0.090	0.280±0.090				
		Discharge standpipe		24.0	42	0.452±0.077	0.429±0.076	0.405±0.075	(39.48)	0.481±0.080	0.456±0.079	0.431±0.079
		Discharge standpipe gear control		21.0	22	0.500±0.107	0.455±0.106	0.318±0.099				
		Discharge diffuser		--	--	--	--	--				
		Discharge diffuser		--	--	--	--	--				
6 JUN	Post-yolk-sac larvae/16 days	Holding controls	2-full (Unit 2)	21.0	50	1.000±0.000	0.960±0.028	0.560±0.070	0.01			
		Intake--pump injected controls		21.0	50	0.840±0.052	0.840±0.052	0.560±0.070				
		Intake--pump gear control		20.0	20	0.950±0.049	0.850±0.080	0.550±0.111				
		Intake--pumpless injected controls		21.0	44	0.932±0.038	0.841±0.055	0.591±0.074				
		Intake--pumpless gear control		21.0	24	0.958±0.041	0.708±0.093	0.542±0.102				
		Discharge standpipe		25.0	58	0.741±0.058	0.741±0.058	0.655±0.062	(57.42)	0.749±0.057	0.749±0.057	0.662±0.062

TABLE L-1 (CONT.)

Release Date	Life Stage/Age	Station/Sample Type	Pump Operation	Temp. (C)	No. of Fish	Proportion Alive[(a)] Initial	Proportion Alive[(a)] 24-Hour	Proportion Alive[(a)] 96-Hour	Prop. Released Dead	Adjusted Proportion Alive Initial	Adjusted Proportion Alive 24-Hour	Adjusted Proportion Alive 96-Hour
6 JUN (cont.)		Discharge standpipe gear control		24.0	28	0.821±0.072	0.714±0.085	0.571±0.094				
		Discharge diffuser		--	--	--	--	--				
		Discharge diffuser gear control		--	--	--	--	--				
12 JUN	Post-yolk-sac larvae/21 days	Holding control	2-full	21.0	50	1.000±0.000	0.960±0.028	0.400±0.069	0.04			
		Intake--pump injected controls		21.0	44	0.864±0.052	0.750±0.065	0.409±0.074				
		Intake--pump gear control		21.0	26	0.846±0.071	0.808±0.077	0.346±0.093				
		Intake--pumpless injected controls		21.0	27	0.963±0.036	0.852±0.068	0.481±0.096				
		Intake--pumpless gear control		21.0	22	1.000±0.000	0.909±0.061	0.545±0.106				
		Discharge standpipe		21.0	37	0.784±0.068	0.676±0.077	0.243±0.071	(35.52)	0.816±0.065	0.704±0.077	0.253±0.073
		Discharge standpipe gear control		21.0	29	0.897±0.056	0.828±0.070	0.379±0.090				
		Discharge diffuser		21.0	16	0.813±0.097	0.750±0.108	0.688±0.116	(15.36)	0.846±0.092	0.781±0.106	0.716±0.115
		Discharge diffuser gear control		20.0	30	0.967±0.033	0.833±0.068	0.400±0.089				
13 JUN	Post-yolk-sac larvae/22 days	Holding controls	2-full	20.0	45	1.000±0.000	0.844±0.054	0.178±0.057	0.09			
		Intake--pump injected controls		21.0	43	0.814±0.059	0.791±0.062	0.302±0.070				
		Intake--pump gear control		21.0	26	0.923±0.052	0.769±0.083	0.192±0.077				
		Intake--pumpless injected controls		21.0	46	0.935±0.036	0.913±0.042	0.391±0.072				
		Intake--pumpless gear control		21.0	22	0.955±0.044	0.727±0.095	0.318±0.099				
		Discharge standpipe		21.0	42	0.881±0.050	0.738±0.068	0.119±0.050	(38.22)	0.968±0.028	0.811±0.063	0.131±0.055
		Discharge standpipe gear control		21.0	21	1.000±0.000	1.000±0.000	0.429±0.108				
		Discharge diffuser		21.0	17	0.882±0.078	0.824±0.092	0.412±0.119	(15.47)	0.970±0.043	0.905±0.075	0.452±0.127
		Discharge diffuser gear control		21.0	24	1.000±0.000	0.958±0.041	0.458±0.102				
19 JUN	Post-yolk-sac larvae/21 days	Holding controls	2-full	23.0	48	1.000±0.000	0.708±0.066	0.167±0.054	0.11			
		Intake--pump injected controls		23.0	46	0.609±0.072	0.391±0.072	0.087±0.042				
		Intake--pump gear control		24.0	26	0.731±0.087	0.577±0.097	0.154±0.071				
		Intake--pumpless injected controls		23.0	46	0.935±0.036	0.826±0.056	0.326±0.069				
		Intake--pumpless gear control		24.0	26	0.923±0.052	0.885±0.063	0.231±0.083				
		Discharge diffuser		27.0	73	0.493±0.059	0.397±0.057	0.082±0.032	(64.97)	0.554±0.062	0.446±0.062	0.092±0.036

TABLE L-1 (CONT.)

Release Date	Life Stage/Age	Station/Sample Type	Pump Operation	Temp. (C)	No. of Fish	Proportion Alive(a)			Prop. Released Dead	Adjusted Proportion Alive		
						Initial	24-Hour	96-Hour		Initial	24-Hour	96-Hour
19 JUN (cont.)		Discharge standpipe gear control		27.0	31	0.742±0.079	0.613±0.087	0.323±0.084				
		Discharge diffuser		26.0	9	0.222±0.139	0.22±0.139	0.111±0.105	(8.01)	0.250±0.153	0.250±0.153	0.125±0.117
		Discharge diffuser gear control		26.0	31	0.903±0.053	0.742±0.079	0.323±0.084				
20 JUN	Post-yolk-sac larvae/22 days	Holding control	2-full	26.0	49	1.000±0.000	0.980±0.020	0.347±0.068	0.05			
		Intake--pump injected controls		24.0	38	0.605±0.079	0.421±0.080	0.132±0.055				
		Intake--pump gear control		24.0	28	0.679±0.088	0.536±0.094	0.107±0.058				
		Intake--pumpless injected controls		24.0	35	0.857±0.059	0.800±0.068	0.171±0.064				
		Intake--pumpless gear control		24.0	32	0.531±0.088	0.438±0.088	0.094±0.052				
		Discharge standpipe		26.0	149	0.383±0.040	0.349±0.039	0.087±0.023	(141.55)	0.403±0.041	0.367±0.041	0.092±0.024
		Discharge standpipe gear control		27.0	28	0.393±0.092	0.250±0.082	0.000± --				
		Discharge diffuser		25.0	29	0.414±0.091	0.345±0.088	0.103±0.056	(27.55)	0.436±0.094	0.363±0.092	0.109±0.059
		Discharge diffuser gear control		27.0	31	0.581±0.089	0.355±0.086	0.129±0.060				
22 JUN	Post-yolk-sac larvae/23 days	Holding controls	2-full	24.0	48	1.000±0.000	0.896±0.044	0.396±0.071	0.29			
		Intake--pump injected controls		23.0	50	0.500±0.071	0.440±0.702	0.220±0.059				
		Intake--pump gear control		23.0	22	0.864±0.073	0.864±0.073	0.364±0.103				
		Intake--pumpless injected controls		23.0	38	0.895±0.050	0.789±0.066	0.368±0.078				
		Intake--pumpless gear control		23.0	26	0.846±0.071	0.846±0.071	0.462±0.098				
		Discharge standpipe		27.0	44	0.614±0.073	0.591±0.074	0.341±0.071	(31.24)	0.864±0.061	0.832±0.067	0.480±0.089
		Discharge standpipe gear control		27.0	25	0.960±0.039	0.920±0.054	0.560±0.099				
		Discharge diffuser		27.0	19	0.526±0.115	0.526±0.115	0.316±0.107	(13.49)	0.741±0.119	0.741±0.119	0.445±0.135
		Discharge diffuser gear control		26.0	26	1.000±0.000	0.962±0.037	0.654±0.093				
25 JUN	Post-yolk-sac larvae/31 days	Holding control	2-full	23.0	50	1.000±0.000	0.980±0.020	0.580±0.070	0.05			
		Intake--pump injected controls		22.0	40	0.825±0.060	0.750±0.068	0.450±0.079				
		Intake--pump gear control		22.0	24	0.958±0.041	0.833±0.076	0.458±0.102				
		Intake--pumpless injected controls		22.0	53	1.000±0.000	1.000±0.000	0.642±0.066				
		Intake--pumpless gear control		22.0	28	0.964±0.035	0.929±0.049	0.607±0.092				
		Discharge standpipe		23.0	30	0.733±0.081	0.733±0.081	0.467±0.091	(28.5)	0.772±0.079	0.772±0.079	0.491±0.094

TABLE L-1 (CONT.)

Release Date	Life Stage/Age	Station/Sample Type	Pump Operation	Temp. (C)	No. of Fish	Proportion Alive[a]			Prop. Released Dead	Adjusted Proportion Alive		
						Initial	24-Hour	96-Hour		Initial	24-Hour	96-Hour
25 JUN (cont.)		Discharge standpipe gear control		23.0	28	0.964±0.035	0.964±0.035	0.429±0.094				
		Discharge diffuser		22.0	6	0.833±0.152	0.833±0.152	0.667±0.192	(5.7)	0.877±0.138	0.877±0.138	0.702±0.192
		Discharge diffuser gear control		22.0	26	1.000±0.000	0.923±0.052	0.500±0.098				

APPENDIX M

ESTIMATED NUMBERS OF ENTRAINED STRIPED BASS AND WHITE PERCH AT THE BOWLINE POINT PLANT COMPARED WITH REGIONAL AND RIVERWIDE STANDING CROPS

APPENDIX M

M-1 Data Sources

Estimates of numbers entrained were derived on a weekly basis to duplicate the weekly interval used for the river ichthyoplankton surveys (TI 1978, 1979, 1980a, 1980b, 1980c). In order to obtain weekly estimates, the densities of entrained post-yolk sac larvae were first calculated for each sampling day using the pumped abundance samples collected at the discharge. Since samples were generally collected on from 3 to 5 days per week, densities for days not sampled were interpolated from the two adjacent sampling dates. The daily numbers entrained (N) were then estimated as follows:

$$N = \text{Volume Pumped} \cdot \text{Density Entrained}$$

The daily numbers were then summed across appropriate weekly intervals.

Standing crop estimates were obtained from data appendixes in the annual year class reports for the Hudson River multiplant impact study (TI 1978, 1979, 1980a, 1980b, 1980c).

TABLE M-1 ESTIMATED NUMBERS ENTRAINED BASED ON DISCHARGE ABUNDANCE SAMPLING AT THE BOWLINE POINT GENERATING STATION COMPARED TO STANDING CROP ESTIMATES[a] FOR 1979

				Standing Crop (1,000's)	
Species	Lifestage[b]	Date	No. Entrained (1,000's)	Croton-Haverstraw	Riverwide
Striped bass	YSL	7-12 MAY	NS[c]	113	4,221
		14-18 MAY	NS	2,837	80,922
		21-24 MAY	0	2,591	198,635
		29 MAY - 1 JUN	0	30,042	257,094
		3-9 JUN	3	1,247	71,249
		10-16 JUN	17	2,847	52,074
		17-23 JUN	66	173	21,397
		25-29 JUN	0	0	2,026
		30 JUN - 1 JUL	7	NS	NS
		2-6 JUL	0	0	288
	PYSL	14-18 MAY	NS	397	1,032
		21-24 MAY	0	1,751	100,995
		30 MAY - 2 JUN	54	28,944	314,550
		3-9 JUN	165	47,599	178,368
		10-16 JUN	260	34,503	189,629
		17-23 JUN	653	27,991	172,183
		24-30 JUN	304	5,593	49,289
		1-7 JUL	62	492	16,738
		11 JUL	6	NS	NS
		16-20 JUL	NS	1,383	3,989
		30 JUL - 3 AUG	NS	0	29
White perch	Eggs	7-12 MAY	NS	538	86,930
		14-18 MAY	NS	23	476,323
		21-26 MAY	160	154	90,329
		27 MAY - 2 JUN	248	0	372,922
		3-9 JUN	928	4,867	200,015
		10-16 JUN	501	21	34,393
		17-23 JUN	108	19	19,710
		24-30 JUN	70	0	233
		1-6 JUL	12	0	0

(a) Data transmittal from Texas Instruments, Inc. (TI), Dr. Irvin Savidge, 10 September 1980.

(b) YSL = yolk sac larvae; PYSL = post yolk-sac larvae.

(c) NS = no sample.

TABLE M-1 (CONT.)

				Standing Crop (1,000's)	
Species	Lifestage	Date	No. Entrained (1,000's)	Croton-Haverstraw	Riverwide
	YSL	7-12 MAY	NS	2,108	52,658
		14-18 MAY	NS	2,495	262,344
		21-24 MAY	0	1,520	89,591
		29 MAY - 2 JUN	1	1,388	119,166
		3-9 JUN	129	4,640	149,251
		10-16 JUN	142	9,096	49,222
		17-23 JUN	194	1,175	20,524
		24-30 JUN	14	0	122
	PYSL	7-12 MAY	NS	27	2,182
		14-18 MAY	NS	4,257	456,812
		21-24 MAY	11	3,496	963,231
		30 MAY - 2 JUN	39	74,352	1,205,235
		3-9 JUN	1,065	45,230	891,405
		10-16 JUN	761	121,689	1,966,504
		17-23 JUN	550	66,087	1,651,631
		24-30 JUN	161	10,375	912,307
		1-7 JUL	47	515	424,252
		8-13 JUL	20	NS	NS
		16-20 JUL	NS	237	68,215

TABLE M-2 ESTIMATED NUMBERS ENTRAINED BASED ON DISCHARGE ABUNDANCE SAMPLING AT THE BOWLINE POINT GENERATING STATION COMPARED TO STANDING CROP ESTIMATES(a) FOR 1978

Species	Lifestage(b)	Date	No. Entrained (1,000's)	Standing Crop (1,000's)	
				Croton-Haverstraw	Riverwide
Striped bass	YSL	15-16 MAY	0	1,975	4,370
		22-25 MAY	0	7,415	51,880
		31 MAY - 3 JUN	115	18,421	183,973
		4-10 JUN	1,881	15,437	308,012
		11-17 JUN	1,233	2,214	16,511
		18-24 JUN	38	33	2,604
		25-29 JUN	52	0	1,989
	PYSL	13-14 MAY	18	0	0
		15-27 MAY	0	0	33
		28 MAY - 3 JUN	39	3,667	76,212
		4-10 JUN	1,465	36,280	439,062
		11-17 JUN	4,530	111,682	413,587
		18-24 JUN	1,164	3,424	65,617
		25 JUN - 1 JUL	606	3,843	23,292
		2-9 JUL	1	98	40,483
	JUV	16-17 JUN	2	0	0
		18-24 JUN	44	0	14
		25 JUN - 1 JUL	166	261	619
		2-6 JUL	25	NS(c)	NS
		7-12 JUL	0	0	2,217
		13-20 JUL	49	1,456	2,424
		31 JUL - 4 AUG	0	205	520
White perch	EGGS	9-13 MAY	192	0	17,129
		14-20 MAY	594	0	141,110
		21-27 MAY	2,990	2,350	332,844
		28 MAY - 3 JUN	2,846	97	1,093,566
		4-10 JUN	945	11,458	132,422
		11-17 JUN	509	22,049	88,021
		18-22 JUN	97	158	23,457
		23-28 JUN	0	0	4,268
		29 JUN - 4 JUL	19	0	0

(a) From TI 1980b.

(b) YSL = yolk sac larvae; PYSL = post yolk sac larvae; JUV = juvenile.

(c) NS = no sample.

TABLE M-2 (CONT.)

Species	Lifestage	Date	No. Entrained (1,000's)	Standing Crop (1,000's) Croton-Haverstraw	Standing Crop (1,000's) Riverwide
White perch	YSL	22-25 MAY	0	8,005	176,043
		27 MAY - 3 JUN	267	10,548	135,598
		4-10 JUN	458	48,688	125,042
		11-17 JUN	258	3,030	57,050
		18-24 JUN	60	154	8,540
		25-26 JUN	19	0	590
		27 JUN - 13 JUL	0	0	0
		14-20 JUL	5	0	0
	PYSL	24-27 MAY	67	6,135	116,612
		28 MAY - 3 JUN	419	29,674	832,362
		4-10 JUN	2,289	72,719	2,497,576
		11-17 JUN	1,681	141,410	2,826,613
		18-24 JUN	542	7,422	984,453
		25 JUN - 1 JUL	549	9,153	423,969
		2-9 JUL	22	0	33,461
		17-20 JUL	0	19	3,177

TABLE M-3 ESTIMATED NUMBERS ENTRAINED BASED ON DISCHARGE ABUNDANCE SAMPLING AT THE BOWLINE POINT GENERATING STATION COMPARED TO STANDING CROP ESTIMATES[a] FOR 1977

Species	Lifestage[b]	Date	No. Entrained (1,000's)	Standing Crop (1,000's)	
				Croton-Haverstraw	Riverwide
Striped bass	YSL	2-5 MAY	NS[c]	48	109
		9-12 MAY	NS	14,039	58,361
		16-19 MAY	6	4,784	94,778
		23-26 MAY	0	16,310	258,966
		31 MAY - 4 JUN	67	3,968	532,853
		6-11 JUN	198	17,619	170,992
		13-16 JUN	0	1,355	21,379
		20-24 JUN	0	75	1,139
	PYSL	17-21 MAY	30	0	9
		22-28 MAY	366	684	2,358
		29 MAY - 4 JUN	1,702	2,202	383,203
		5-11 JUN	4,146	81,816	559,425
		12-18 JUN	592	6,539	273,199
		19-25 JUN	119	10,739	78,867
		26 JUN - 1 JUL	98	1,842	29,112
		2-6 JUL	56	934	3,732
		11-15 JUL	0	131	688
	JUV	15-18 JUN	62	0	0
		19-20 JUN	22	0	0
		21-26 JUN	0	0	0
		27 JUN - 1 JUL	324	39	2,241
		2-8 JUL	139	416	3,305
		9-15 JUL	25	990	2,507
		16-20 JUL	13	NS	NS
		25-31 JUL	9	5,768	11,106
		8-12 AUG	0	39	8,369
White perch	EGGS	12-14 MAY	236	37	41,180
		15-21 MAY	1,837	432	26,232
		22-28 MAY	1,429	223	139,043
		29 MAY - 4 JUN	389	19	32,908
		5-9 JUN	4	638	23,385
		13-16 JUN	0	8,571	9,461
		17-20 JUN	28	NS	NS
		21-24 JUN	0	0	2,695
		19-20 JUL	14	0	0

(a) TI 1980b.

(b) YSL = yolk sac larvae; PYSL = post yolk sac larvae; JUV = juvenile.

(c) NS = no sample.

TABLE M-3 (CONT.)

Species	Lifestage	Date	No. Entrained (1,000's)	Standing Crop (1,000's) Croton-Haverstraw	Standing Crop (1,000's) Riverwide
White perch	YSL	16-19 MAY	0	430	79,627
		23-28 MAY	35	13,330	300,735
		29-31 MAY	13	3,616	116,207
		6-9 JUN	0	1,364	53,050
		13-16 JUN	0	85	3,307
		20-25 JUN	57	77	1,261
	PYSL	20-21 MAY	6	120	3,154
		22-28 MAY	326	2,370	232,995
		29 MAY - 4 JUN	686	2,113	1,490,746
		5-11 JUN	882	34,992	1,846,626
		12-18 JUN	112	1,630	1,413,347
		19-25 JUN	106	5,238	463,065
		26 JUN - 1 JUL	126	905	230,362
		2-8 JUL	55	3,076	50,146
		9-11 JUL	21	132	20,981

TABLE M-4 ESTIMATED NUMBERS ENTRAINED BASED ON DISCHARGE ABUNDANCE SAMPLING AT THE BOWLINE POINT GENERATING STATION COMPARED TO STANDING CROP ESTIMATES(a) FOR 1976

				Standing Crop (1,000's)	
Species	Lifestage(b)	Date	No. Entrained (1,000's)	Croton-Haverstraw	Riverwide
Striped bass	YSL	2-8 MAY	27	0	59
		9-15 MAY	119	440	1,733
		16-22 MAY	84	9,647	116,399
		23-29 MAY	25	3,603	18,150
		1-4 JUN	0	1,482	47,796
		7-12 JUN	13	2,771	100,651
		13-19 JUN	90	3,541	152,272
		20-21 JUN	11	87	15,034
	PYSL	3-5 JUN	3	284	804
		6-12 JUN	78	1,295	24,191
		13-19 JUN	446	14,373	242,065
		20-26 JUN	1,431	44,789	184,805
		27 JUN - 3 JUL	846	8,899	47,211
		4-10 JUL	272	1,674	8,320
		11-17 JUL	148	75	1,863
		18-19 JUL	5	0	0
	JUV	28 JUN - 3 JUL	3	0	7
		4-10 JUL	31	161	1,749
		11-15 JUL	25	167	2,248
		22-24 JUL	4	NS(c)	NS
		25-29 JUL	10	1,535	4,180
		10-13 AUG	0	115	1,235
White perch	EGGS	26 APR - 1 MAY	36	0	31,375
		2-8 MAY	2,296	7,448	103,753
		9-15 MAY	1,104	3,834	118,939
		16-22 MAY	928	2,771	436,759
		23-29 MAY	4,998	27,027	83,164
		30 MAY - 5 JUN	826	1,013	243,047
		6-12 JUN	199	3,058	375,801
		13-19 JUN	389	116	62,523
		20-26 JUN	62	1,608	13,028
		27 JUN - 3 JUL	97	592	1,144
		4-6 JUL	9	0	888

(a) TI 1979.

(b) YSL = yolk sac larvae; PYSL = post yolk-sac larvae.

(c) NS = no sample.

TABLE M-4 (CONT.)

Species	Lifestage	Date	No. Entrained (1,000's)	Standing Crop (1,000's) Croton-Haverstraw	Standing Crop (1,000's) Riverwide
White perch	YSL	3-5 MAY	0	69	25,977
		10-13 MAY	0	12,927	85,486
		14-19 MAY	16	8,409	292,892
		20-31 MAY	0	13,129	83,922
		1-5 JUN	3	1,446	60,098
		6-12 JUN	44	2,494	116,627
		13-19 JUN	9	1,377	149,997
		20-22 JUN	10	304	17,723
		28 JUN - 1 JUL	0	199	663
	PYSL	2-8 MAY	5	15	1,134
		9-15 MAY	55	3,361	12,326
		16-22 MAY	71	3,115	77,372
		23-29 MAY	124	36,792	137,918
		30 MAY - 5 JUN	179	6,260	30,207
		6-12 JUN	31	1,434	442,733
		13-19 JUN	34	7,369	1,708,436
		20-26 JUN	165	20,870	2,080,263
		27 JUN - 3 JUL	410	18,380	675,509
		4-10 JUL	229	11,996	205,945
		11-17 JUL	320	2,304	189,160
		18-24 JUL	28	NS	4,992

TABLE M-5 ESTIMATED NUMBERS ENTRAINED BASED ON DISCHARGE ABUNDANCE SAMPLING AT THE BOWLINE POINT GENERATING STATION COMPARED TO STANDING CROP ESTIMATES[a] FOR 1975

Species	Lifestage[b]	Date	No. Entrained (1,000's)	Standing Crop (1,000's)	
				Croton-Haverstraw	Riverwide
Striped bass	YSL	8-11 MAY	1	0	0
		12-18 MAY	7	172	508
		19-25 MAY	12	5,884	41,866
		26 MAY - 1 JUN	18	30,481	492,458
		2-8 JUN	26	56,258	397,964
		9-14 JUN	1	1,065	8,323
		16-19 JUN	0	104	1,370
	PYSL	8-11 MAY	2	0	0
		12-18 MAY	13	0	0
		19-25 MAY	24	0	130
		26 MAY - 1 JUN	35	2,354	18,306
		2-8 JUN	314	47,024	716,670
		9-15 JUN	1,155	75,808	572,990
		16-22 JUN	478	4,234	43,082
		23-29 JUN	188	1,933	31,905
		30 JUN - 4 JUL	8	89	12,820
White perch	PSYL	8-10 MAY	1	NS[c]	NS
		11-17 MAY	8	0	0
		18-24 MAY	19	102	13,773
		25-31 MAY	28	35,788	832,656
		1-7 JUN	351	58,143	1,378,144
		8-14 JUN	1,446	61,495	797,302
		15-21 JUN	1,056	19,997	178,107
		22-28 JUN	665	31,064	339,745
		29 JUN - 4 JUL	217	7,236	224,029
		7-10 JUL	0	139	56,802
		14-19 JUL	3	837	15,892
		20-24 JUL	8	38	2,421
		28-31 JUL	0	103	1,045

(a) TI 1978.
(b) YSL = yolk sac larvae; PYSL = post yolk-sac larvae.
(c) NS = no sample.

APPENDIX N

SUMMARY OF RESULTS FOR STATISTICAL ANALYSES PERFORMED TO EVALUATE ICHTHYOPLANKTON ENTRAINMENT SURVIVAL AT THE BOWLINE POINT PLANT, 1979

TABLE N-1 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG STATION, INITIAL SURVIVAL, AND COLLECTION GEAR FOR ENTRAINMENT SURVIVAL STUDIES AT THE BOWLINE POINT PLANT, 1979

Striped Bass Post Yolk-Sac Larvae

Source	df	G
Gear x station independence	1	14.32**
Station x survival independence	1	14.12**
Gear x survival independence	1	0.00
Gear x station x survival interaction	1	1.26
Gear x station x survival independence	4	29.70**

White Perch Post Yolk-Sac Larvae

Source	df	G
Gear x station independence	1	2.68
Station x survival independence	1	22.46**
Gear x survival independence	1	3.40
Gear x station x survival interaction	1	111.86**
Gear x station x survival independence	4	140.40**

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df = degrees of freedom
G = test statistic
** denotes $p \leq 0.001$

TABLE N-2 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG STATION, NORMALIZED SURVIVAL (24 hours), AND COLLECTION GEAR FOR ENTRAINMENT SURVIVAL STUDIES AT THE BOWLINE POINT PLANT, 1979

Striped Bass Post Yolk-Sac Larvae

Source	df	G
Gear x station independence	1	8.60*
Station x survival independence	1	11.52**
Gear x survival independence	1	0.68
Gear x station x survival interaction	1	3.56
Gear x station x survival independence	4	24.36**

White Perch Post Yolk-Sac Larvae

Source	df	G
Gear x station independence	1	10.76*
Station x survival independence	1	8.40*
Gear x survival independence	1	0.34
Gear x station x survival interaction	1	0.86
Gear x station x survival independence	4	20.36**

---

df = degrees of freedom
G = test statistic
* denotes $p \leq 0.05$
** denotes $p \leq 0.001$

TABLE N-3 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG STATION, SURVIVAL NORMALIZED TO THE PREVIOUS LATENT EFFECTS OBSERVATION, AND OBSERVATION TIME (24, 48, 72, and 96 Hours) FOR ENTRAINMENT SURVIVAL STUDIES AT THE BOWLINE POINT PLANT, 1979

Striped Bass - Plankton Flume

Source	df	G
Station x time independence	3	1.14
Station x survival independence	1	1.04
Time x survival independence	3	4.78
Station x time x survival interaction	3	3.08
Station x time x survival independence	10	8.98

Striped Bass - Larval Table

Source	df	G
Station x time independence	3	0.08
Station x survival independence	1	0.00
Time x survival independence	3	0.62
Station x time x survival interaction	3	4.16
Station x time x survival independence	10	4.86

White Perch - Plankton Flume

Source	df	G
Station x time independence	3	0.10
Station x survival independence	1	0.06
Time x survival independence	3	8.78*
Station x time x survival interaction	3	5.10
Station x time x survival independence	10	14.04

---

df = degrees of freedom
G = test statistic
* denotes $p \leq 0.05$
** denotes $p \leq 0.001$

TABLE N-3 (CONT.)

White Perch - Larval Table

Source	df	G
Station x time independence	3	0.26
Station x survival independence	1	0.04
Time x survival independence	3	16.36**
Station x time x survival interaction	3	3.74
Station x time x survival independence	10	20.40*

TABLE N-4 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG COLLECTION GEAR, SURVIVAL, AND THE PRESENCE OR ABSENCE OF SUBLETHAL THERMAL STRESS DURING ENTRAINMENT AT THE BOWLINE POINT PLANT, 1979

Striped Bass - Initial

Source	df	G
Gear x stress independence	1	3.36
Stress x survival independence	1	0.38
Gear x survival independence	1	0.52
Gear x stress x survival interaction	1	2.72
Gear x stress x survival independence	4	6.98

Striped Bass - Normalized 24-Hr.

Source	df	G
Gear x stress independence	1	6.00*
Stress x survival independence	1	0.94
Gear x survival independence	1	1.34
Gear x stress x survival interaction	1	1.06
Gear x stress x survival independence	4	9.50*

---

df = degrees of freedom
G = test statistic
* denotes $p \leq 0.05$
** denotes $p \leq 0.001$

TABLE N-4 (CONT.)

White Perch - Initial

Source	df	G
Gear x stress independence	1	1.40
Stress x survival independence	1	0.30
Gear x survival independence	1	10.78*
Gear x stress x survival interaction	1	7.48*
Gear x stress x survival independence	4	19.96**

White Perch - Normalized 24-Hr.

Source	df	G
Gear x stress independence	1	7.56*
Stress x survival independence	1	0.00
Gear x survival independence	1	1.56
Gear x stress x survival interaction	1	0.24
Gear x stress x survival independence	4	9.36

TABLE N-5 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS OF INDEPENDENCE AMONG DISCHARGE SITE (Standpipe vs. Diffuser), SURVIVAL, AND PRESENCE OR ABSENCE OF SUBLETHAL THERMAL STRESS DURING ENTRAINMENT AT THE BOWLINE POINT PLANT, 1979

Striped Bass - Initial

Source	df	G
Stress x discharge site independence	1	0.16
Stress x survival independence	1	5.70*
Discharge site x survival independence	1	0.76
Discharge site x stress x survival interaction	1	2.72
Discharge site x stress x survival independence	4	9.04

Striped Bass - Normalized 24-Hr.

Source	df	G
Stress x discharge site independence	1	2.02
Stress x survival independence	1	0.00
Discharge site x survival independence	1	3.78
Discharge site x stress x survival interaction	1	2.04
Discharge site x stress x survival independence	4	7.87

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df = degrees of freedom
G = test statistic
* denotes $p \leq 0.05$

TABLE N-5 (CONT.)

White Perch - Initial

Source	df	G
Stress x discharge site independence	1	1.34
Stress x survival independence	1	3.16
Discharge site x survival independence	1	1.84
Discharge site x stress x survival interaction	1	0.80
Discharge site x stress x survival independence	4	7.14

White Perch - Normalized 24-Hr.

Source	df	G
Stress x discharge site independence	1	0.20
Stress x survival independence	1	3.16
Discharge site x survival independence	1	0.50
Discharge site x stress x survival interaction	1	2.48
Discharge site x stress x survival independence	4	6.34

TABLE N-6 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG GEAR, STATION, AND INITIAL SURVIVAL OF HATCHERY-REARED STRIPED BASS EGGS AND LARVAE USED IN DIRECT-RELEASE STUDIES AT THE BOWLINE POINT POWER PLANT, 1979

Eggs

Source	df	G
Gear x station independence	1	4.62*
Station x survival independence	1	33.84**
Gear x survival independence	1	47.24**
Gear x station x survival interaction	1	-4.62*
Gear x station x survival independence	4	81.08**

Yolk-Sac Larvae

Source	df	G
Gear x station independence	1	19.94**
Station x survival independence	1	2.36
Gear x survival independence	1	10.18*
Gear x station x survival interaction	1	0.26
Gear x station x survival independence	4	32.74**

---

df = degrees of freedom
G = test statistic
* denotes $p \leq 0.05$
** denotes $p \leq 0.001$

TABLE N-6 (CONT.)

Post Yolk-Sac Larvae

Source	df	G
Gear x station independence	1	145.24**
Station x survival independence	1	38.62**
Gear x survival independence	1	51.44**
Gear x station x survival interaction	1	4.04*
Gear x station x survival independence	4	239.34**

TABLE N-7 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG GEAR, STATION, AND PERCENT HATCH FOR EGGS OR 24-HR SURVIVAL OF HATCHERY-REARED STRIPED BASS EGGS AND LARVAE USED IN DIRECT RELEASE STUDIES AT THE BOWLINE POINT PLANT, 1979

Eggs

Source	df	G
Gear x station independence	1	0.0
Station x survival independence	1	0.82
Gear x survival independence	1	10.34**
Gear x station x survival interaction	1	2.52
Gear x station x survival independence	4	13.68**

Yolk-Sac Larvae

Source	df	G
Gear x station independence	1	1.24
Station x survival independence	1	2.38
Gear x survival independence	1	2.24
Gear x station x survival interaction	1	1.08
Gear x station x survival independence	4	6.94

---

df = degrees of freedom
G = test statistic
* denotes $p \leq 0.05$
** denotes $p \leq 0.001$

TABLE N-7 (CONT.)

Post Yolk-Sac Larvae

Source	df	G
Gear x station independence	1	143.78**
Station x survival independence	1	3.80
Gear x survival independence	1	0.14
Gear x station x survival interaction	1	0.08
Gear x station x survival independence	4	147.80**

TABLE N-8 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG STATION, INITIAL SURVIVAL, AND TOTAL LENGTH (mm) OF HATCHERY-REARED STRIPED BASS USED IN THE DIRECT RELEASE STUDIES AND COLLECTED IN THE PUMPED AND PUMPLESS SYSTEMS AT THE BOWLINE POINT PLANT, 1979

Pumped Larval Tables

Source	df	G
Total length x station independence	3	64.28**
Station x survival independence	1	5.36*
Total length x survival independence	3	31.20**
Total length x station x survival interaction	3	4.64
Total length x station x survival independence	10	105.48**

Pumpless Plankton Sampling Flume

Source	df	G
Total length x station independence	3	31.18**
Station x survival independence	1	16.18**
Total length x survival independence	3	87.54**
Total length x station x survival interaction	3	55.48**
Total length x station x survival independence	10	190.38**

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df = degrees of freedom
G = test statistic
* denotes $p \leq 0.05$
** denotes $p \leq 0.001$

TABLE N-9 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG STATION, LATENT (24-hour) SURVIVAL, AND TOTAL LENGTH (mm) OF HATCHERY-REARED STRIPED BASS USED IN THE DIRECT RELEASE STUDIES AND COLLECTED IN THE PUMPED AND PUMPLESS SYSTEMS AT THE BOWLINE POINT PLANT, 1979

Pumped Larval Tables

Source	df	G
Total length x station independence	3	32.22*
Station x survival independence	1	5.78*
Total length x survival independence	3	35.64**
Total length x station x survival interaction	3	16.80**
Total length x station x survival independence	10	90.44

Pumpless Plankton Sampling Flume

Source	df	G
Total length x station independence	3	9.92*
Station x survival independence	1	0.54
Total length x survival independence	3	35.06**
Total length x station x survival interaction	3	220.46**
Total length x station x survival independence	10	265.98**

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df = degrees of freedom
G = test statistic
* denotes $p \leq 0.05$
** denotes $p \leq 0.001$

TABLE N-10 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG STATION, INITIAL AND 24-HOUR SURVIVAL, AND ORIGIN OF HATCHERY-REARED AND WILD STRIPED BASS POST YOLK-SAC LARVAE COLLECTED AT THE BOWLINE POINT PLANT, 1979

Initial

Source	df	G
Station x origin independence	3	57.12**
Station x survival independence	3	107.62**
Intake pump x intake pumpless independence	1	45.72**
Discharge pump x discharge pumpless independence	1	1.54
Intake x discharge independence	1	60.35**
Survival x origin independence	1	20.02**
Station x origin x survival interaction	3	2.60
Station x origin x survival independence	10	187.36**

(24-Hour)

Source	df	G
Station x origin independence	3	14.08*
Station x survival independence	3	3.76
Survival x origin independence	1	27.16**
Station x origin x survival interaction	3	16.02*
Station x origin x survival independence	10	61.02**

---

df = degrees of freedom
G = test statistic
* denotes $p \leq 0.05$
** denotes $p \leq 0.001$

APPENDIX O

ANNUAL LENGTH-FREQUENCY SUMMARIES FOR STRIPED BASS, WHITE PERCH, AND ATLANTIC TOMCOD COLLECTED DURING ENTRAINMENT STUDIES AT THE BOWLINE POINT PLANT, 1975-1979

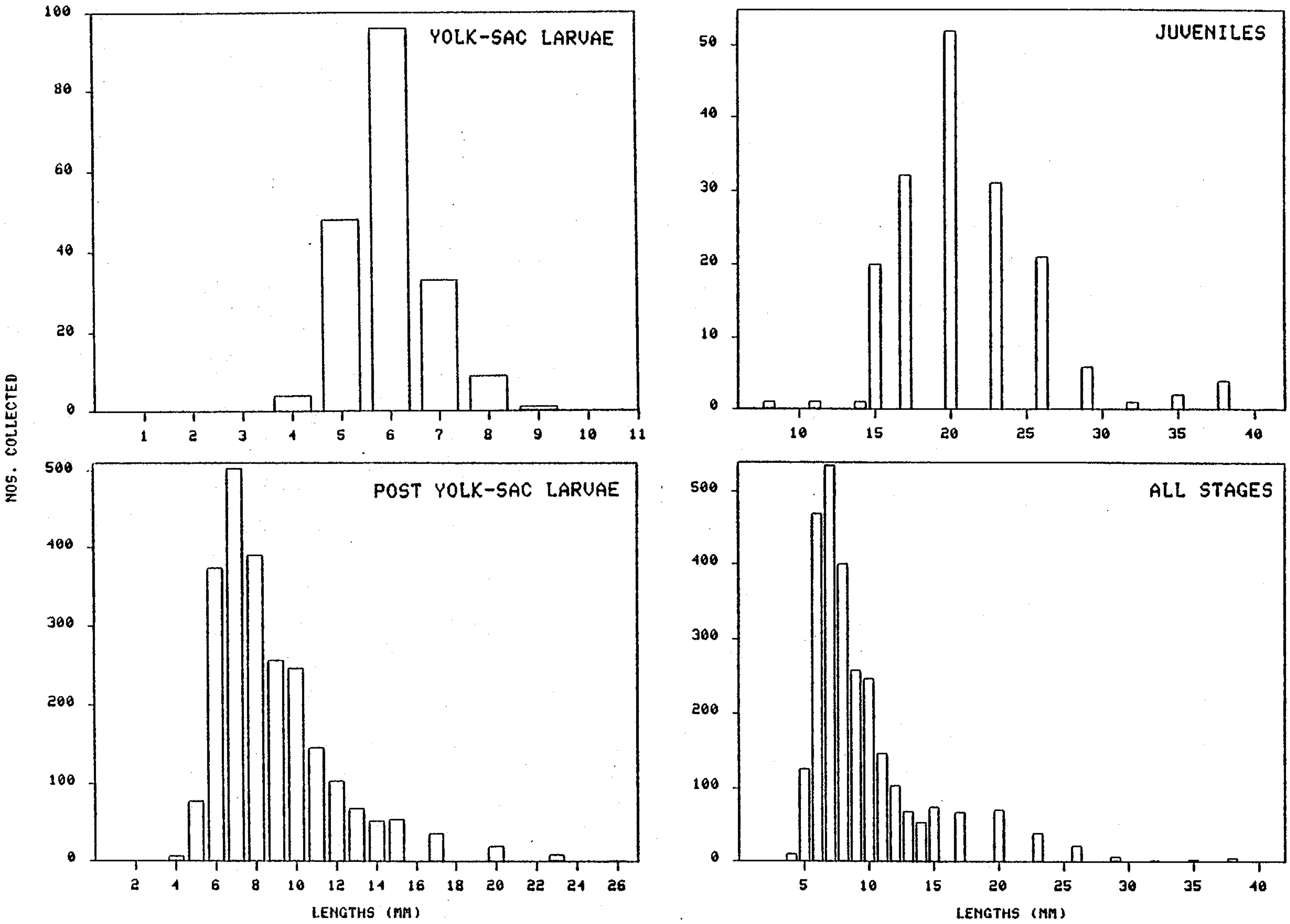

Figure 0-1. Length frequency histograms for striped bass by life stage and for all life stages combined collected during entrainment survival studies at the Bowline Point plant, 1975—1979.

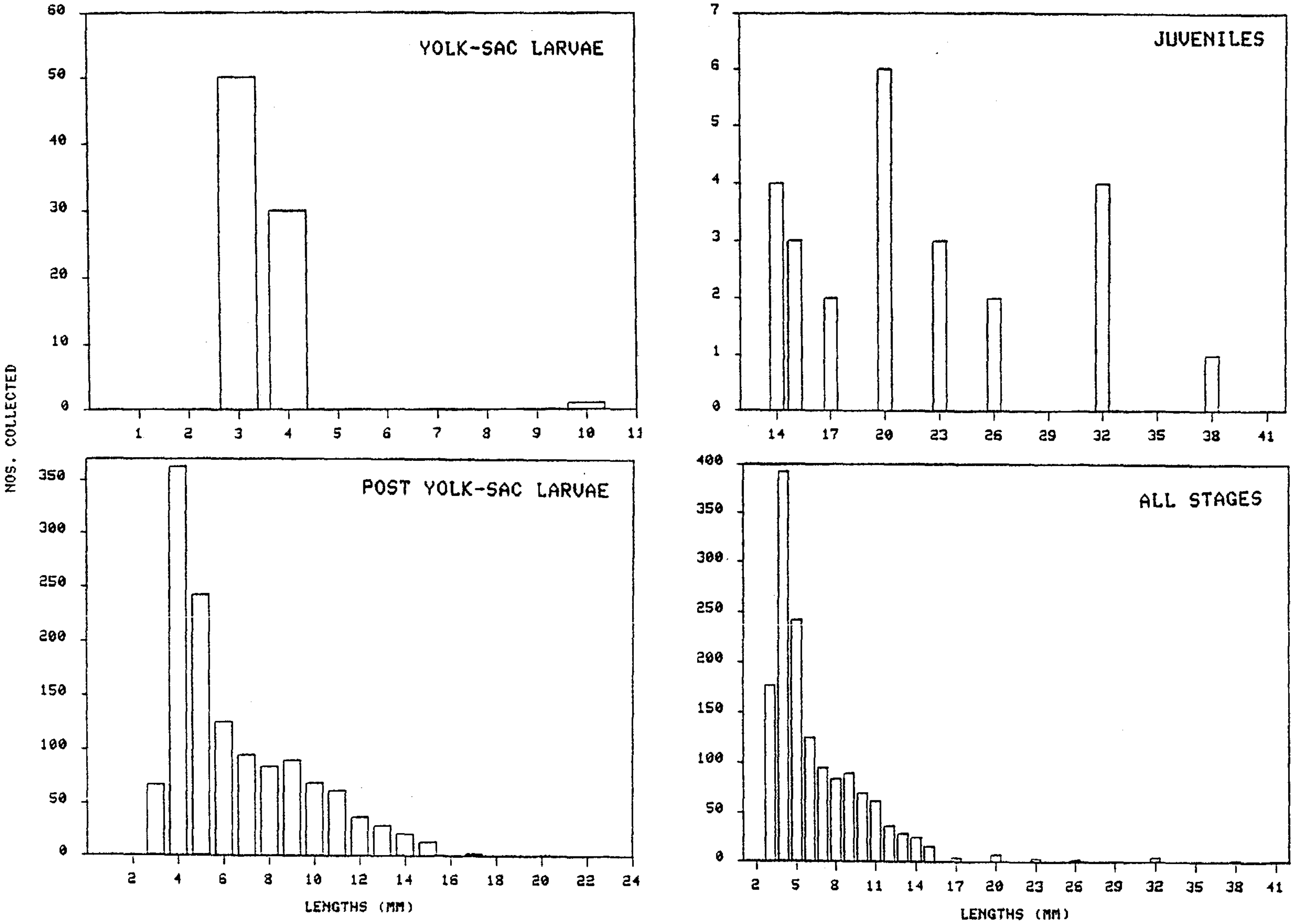

Figure 0-2. Length frequency histograms for white perch by life stage and for all life stages combined collected during entrainment survival studies at the Bowline Point plant, 1975–1979.

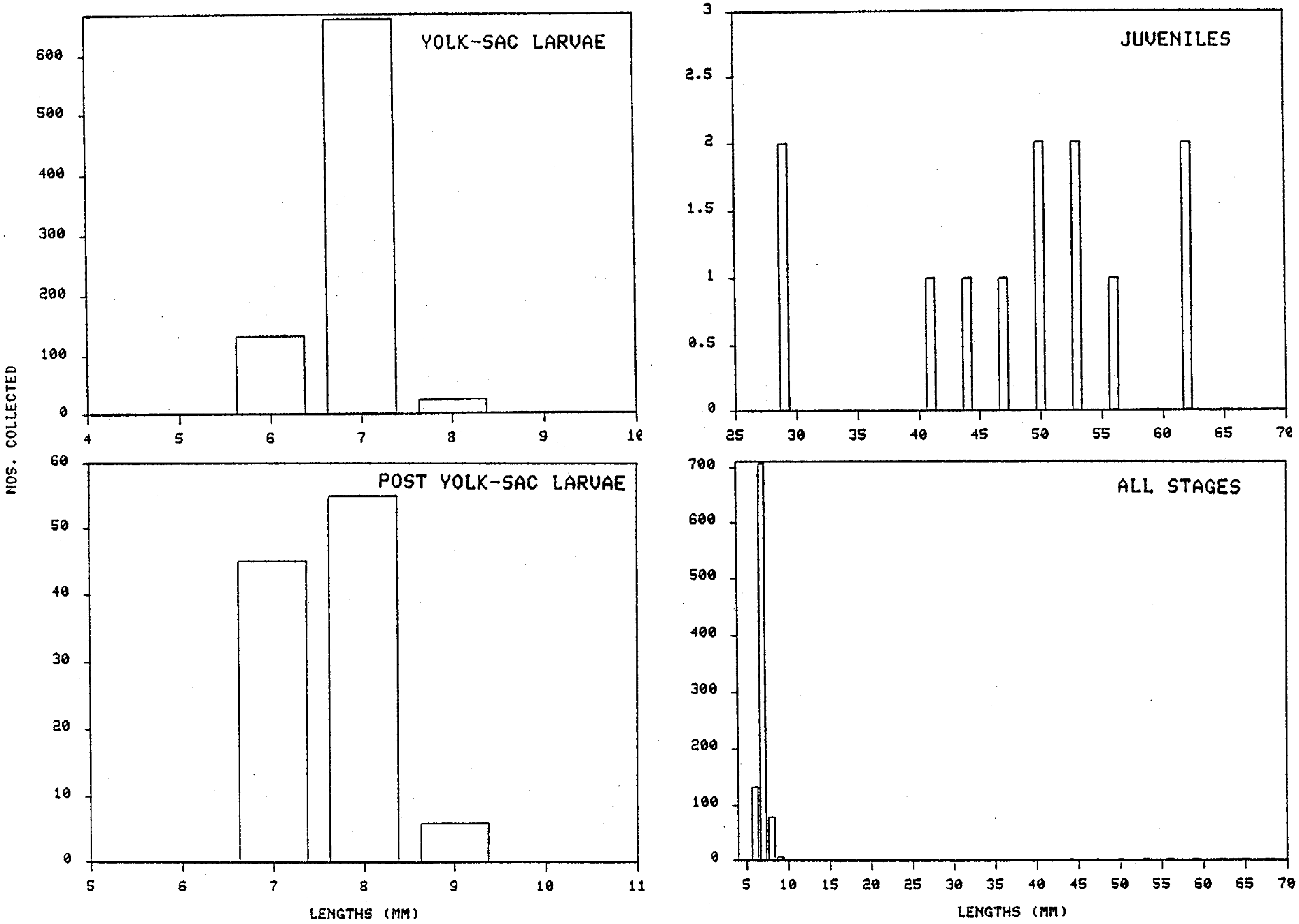

Figure 0-3. Length frequency histograms for Atlantic tomcod by life stage and for all life stages combined collected during entrainment survival studies at the Bowline Point plant, 1976—1977.

TABLE O-1 YEARLY SUMMARY BY LIFE STAGE AND LENGTH FOR STRIPED BASS COLLECTED AT THE BOWLINE POINT PLANT DURING ENTRAINMENT SURVIVAL STUDIES, 1975-1979

Year	Sampling Season	Life Stage	Number	Mean Length	Min. Length	Max. Length	Percent at	Peak Length Interval (mm)	Mode
1975	03 JUN-25 AUG	PYSL	246	7.50	4	13	43	7	
		Combined	250	7.54	4	20	42	7	7
1976	18 MAY-29 JUL	YSL	11	5.82	4	7	54	6	
		PYSL	312	9.07	4	23	33	6	
		JUV	53	25.17	11	38	32	23	
		Combined	376	11.24	4	38	29	6	6
1977	23 MAY-15 JUL	YSL	9	6.22	5	7	56	6	
		PYSL	651	9.17	5	23	23	7	
		JUV	95	19.95	14	32	34	20	
		Combined	755	10.39	5	32	20	7	7-8
1978	22 MAY-21 JUL	YSL	133	6.08	4	9	46	6	
		PYSL	918	9.00	5	17	17	8	
		JUV	21	18.71	15	26	52	20	
		Combined	1,072	8.83	4	26	16	7	6-10
1979	23 MAY-27 JUN	YSL	37	5.73	4	8	62	6	
		PYSL	217	7.59	5	13	31	6	
		Combined	254	7.32	4	13	35	6	6
1975-1979		YSL	191	5.99	4	9	50	6	
		PYSL	2,344	8.78	4	23	21	7	
		JUV	172	20.95	8	38	30	20	
		Combined	2,707	9.35	4	38	20	7	6-8

Note: YSL = yolk-sac larvae; PYSL = post yolk-sac larvae; JUV = juvenile.

TABLE O-2 YEARLY SUMMARY BY LIFE STAGE AND LENGTH FOR WHITE PERCH COLLECTED AT THE BOWLINE POINT PLANT DURING ENTRAINMENT SURVIVAL STUDIES, 1975-1979

Year	Sampling Season	Life Stage	Number	Mean Length	Min. Length	Max. Length	Percent at	Peak Length Interval (mm)	Mode
1975	03 JUN-25 AUG	PYSL	288	8.88	3	20	12	11	
		Combined	289	8.82	3	20	12	11	4-13
1976	18 MAY-29 JUL	PYSL	91	8.65	3	17	18	5	
		JUV	14	24.36	14	38	28	32	
		Combined	106	10.67	3	38	15	5	5, 10, 14, 32
1977	23 MAY-15 JUL	PYSL	62	8.87	3	17	19	8	
		JUV	7	20.00	14	26	42	20	
		Combined	69	10.00	3	26	17	8	5, 8, 14, 20
1978	22 MAY-21 JUL	YSL	31	3.39	3	4	61	3	
		PYSL	483	5.79	3	14	30	4	
		Combined	518	5.69	3	17	31	4	4
1979	23 MAY-27 JUN	YSL	48	3.38	3	4	62	3	
		PYSL	376	4.84	3	12	48	4	
		Combined	424	4.68	3	12	47	4	4
1975-1979		YSL	81	3.33	3	4	62	3	
		PYSL	1,300	6.54	3	15	27	4	
		JUV	25	20.48	14	38	24	20	
		Combined	1,406	6.63	3	38	28	4	4-5

Note: YSL = yolk-sac larvae; PYSL = post yolk-sac larvae; JUV = juvenile.

TABLE O-3 YEARLY SUMMARY BY LIFE STAGE AND LENGTH FOR ATLANTIC TOMCOD COLLECTED AT THE BOWLINE POINT PLANT DURING ENTRAINMENT SURVIVAL STUDIES, 1975-1979

Year	Sampling Season	Life Stage	Number	Mean Length	Min. Length	Max. Length	Percent at	Peak Length Interval (mm)	Mode
1976	No length information was collected								
1977	23 MAY-15 JUL	YSL	808	6.86	6	8	81	7	
		PYSL	8	7.50	7	8	50	7 and 8	
		Combined	818	8.11	6	53	81	7	7
1978	22 MAY-21 JUL	YSL	11	7.27	6	8	54	7	
		PYSL	98	7.64	7	9	52	8	
		JUV	9	48.66	29	65	22	56 and 29	
		Combined	118	10.28	6	65	47	8	7-8
Years Combined		YSL	819	6.87	6	8	80	7	
		PYSL	106	7.63	7	9	52	8	
		JUV	12	50.50	29	65	17	29, 53, 56, and 65	
		Combined	937	7.51	6	65	75	7	7

Note: YSL = yolk-sac larvae; PYSL = post yolk-sac larvae; JUV = juvenile.

APPENDIX P

SUMMARY OF RESULTS FOR STATISTICAL ANALYSES PERFORMED TO EVALUATE ICHTHYOPLANKTON ENTRAINMENT SURVIVAL AT THE BOWLINE POINT PLANT, 1975-1979

TABLE P-1 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG YEAR, LENGTH, AND SURVIVAL OF WHITE PERCH COLLECTED AT THE BOWLINE POINT PLANT, 1975-1979

Intake

Source	df	G
Length x survival independence	11	108.08 **
Length x year independence	44	227.65 **
Year x survival independence	4	33.37 **
Length x year x survival interaction	44	31.54
Length x year x survival independence	103	400.74 **

Discharge

Source	df	G
Length x survival independence	10	195.04 **
Length x year independence	40	452.20 **
Year x survival independence	4	117.83 **
Length x year x survival interaction	40	39.29
Length x year x survival independence	94	804.36 **

Note: df = degrees of freedom
G = test statistic
** denotes $p < 0.001$

TABLE P-2 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG YEAR, LENGTH, AND SURVIVAL OF STRIPED BASS COLLECTED AT THE BOWLINE POINT PLANT

Intake (1975-1977)

Source	df	G
Length x survival independence	9	15.35
Length x year independence	18	124.67 **
Year x survival independence	2	0.83
Length x year x survival interaction	18	15.66
Length x year x survival independence	47	156.51 **

Discharge (1975-1978)

Source	df	G
Length x survival independence	13	70.40 **
Length x year independence	39	319.53 **
Year x survival independence	3	40.47 **
Length x year x survival interaction	39	65.28 *
Length x year x survival independence	94	495.68 **

Note: df = degrees of freedom
G = test statistic
* denotes $0.01 > p > 0.005$
** denotes $p < 0.001$

TABLE P-3 SUMMARY OF THREE-WAY CONTINGENCY ANALYSES FOR INDEPENDENCE AMONG OBSERVATION INTERVAL, STATION, AND SURVIVAL (normalized to previous observation interval) BETWEEN 24 AND 96 HOURS FOR STRIPED BASS, WHITE PERCH, AND ATLANTIC TOMCOD COLLECTED AT THE BOWLINE POINT PLANT AND POOLED BY 1-mm LENGTH INTERVAL

Length (mm)	Observation x Survival	Observation x Station	Station x Survival	Observation x Station x Survival
		Striped Bass		
4	N.S.	N.S.	N.S.	N.S.
5	N.S.	N.S.	$p=0.05$	N.S.
6	N.S.	N.S.	N.S.	N.S.
7	$P \leq 0.001$	N.S.	N.S.	N.S.
8	$p \leq 0.05$	N.S.	N.S.	N.S.
9	$p \leq 0.05$	N.S.	N.S.	N.S.
10	N.S.	N.S.	N.S.	N.S.
11	N.S.	N.S.	N.S.	N.S.
12	N.S.	N.S.	N.S.	N.S.
13	N.S.	N.S.	N.S.	N.S.
14	N.S.	N.S.	N.S.	N.S.
15	N.S.	N.S.	N.S.	N.S.
16	N.S.	N.S.	N.S.	N.S.
		White Perch		
3	N.S.	N.S.	N.S.	N.S.
4	$p \leq 0.05$	N.S.	N.S.	N.S.
5	$p \leq 0.05$	N.S.	N.S.	N.S.
6	N.S.	N.S.	N.S.	N.S.
7	N.S.	N.S.	N.S.	N.S.
8	N.S.	N.S.	N.S.	N.S.
9	N.S.	N.S.	N.S.	N.S.
10	$p \leq 0.05$	N.S.	N.S.	N.S.
11	N.S.	N.S.	N.S.	N.S.
12	N.S.	N.S.	N.S.	N.S.
13	N.S.	N.S.	N.S.	N.S.
14	N.S.	N.S.	N.S.	N.S.
15	N.S.	N.S.	N.S.	N.S.
		Atlantic Tomcod		
All lengths	N.S.	N.S.	N.S.	N.S.

Note: N.S. denotes not significant; $p>0.05$.

TABLE P-4 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG LENGTH, STATION, AND SURVIVAL AT 24 HOURS (NORMALIZED) FOR WHITE PERCH AND STRIPED BASS AT THE BOWLINE POINT PLANT

White Perch

Source	df	G
Length x station independence	12	33.17*
Length x survival independence	12	35.67*
Station x survival independence	1	10.28*
Length x station X survival interaction	12	15.51
Length x station x survival independence	37	94.63*

Striped Bass

Source	df	G
Length x station independence	12	85.78*
Length x survival independence	12	124.94*
Station x survival independence	1	0.48
Length x station x survival interaction	12	8.92
Length x station x survival independence	37	220.12*

Note: df = degrees of freedom
G = test statistic
* denotes $p \leq 0.001$

TABLE P-5 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG PUMP MODE, LENGTH, AND SURVIVAL OF STRIPED BASS AND WHITE PERCH COLLECTED AT THE BOWLINE POINT PLANT INTAKE

Striped Bass

Source	df	G
Length x pump mode independence	36	129.31**
Pump mode x survival independence	3	2.99
Length x survival independence	12	17.17
Pump mode x length x survival interaction	36	25.54
Pump mode x length x survival independence	87	175.01**

White Perch

Source	df	G
Length x pump mode independence	12	48.95**
Pump mode x survival independence	1	1.76
Length x survival independence	12	87.09**
3-4 mm x survival independence	1	7.58**
5-7 mm x survival independence	2	0.61
8+ mm x survival independence	7	4.84
Length group x survival independence	2	89.01**
Pump mode x length x survival interaction	12	10.16
Pump mode x length x survival independence	37	147.96**

Note: df = degrees of freedom
G = test statistic
** denotes $p < 0.001$

TABLE P-6 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG PUMP MODE, LENGTH, AND SURVIVAL OF WHITE PERCH COLLECTED AT THE BOWLINE POINT PLANT DISCHARGE INITIALLY AND 24 HOURS FOLLOWING ENTRAINMENT, 1975-1979

	df	Marginal Association	Partial Association
Initial			
Length x pump mode independence	12	265.37**	173.35**
Pump mode x survival independence	1	101.03**	9.02*
Length x survival independence	12	182.46**	90.45**
3-4 mm x survival independence	1	0.64	
5-7 mm x survival independence	2	3.20	
8-11 mm x survival independence	3	1.36	
12+ mm x survival independence	3	1.53	
Length group x survival independence	3	184.59**	
Pump mode x length x survival interaction	12	10.72	
Pump mode x length x survival independence	37	559.58**	
24-Hour (Non-normalized)			
Length x pump mode independence	12	265.37**	213.28**
Pump mode x survival independence	1	53.21**	1.13
Length x survival independence	12	132.63**	80.54**
3-7 mm x survival independence	4	7.76	
8+ mm x survival independence	7	7.69	
Length group x survival independence	1	116.93**	
Pump mode x length x survival interaction	12	14.90	
Pump mode x length x survival independence	37	466.11**	

Note: df = degrees of freedom
* denotes 0.01 > p > 0.001
** denotes p < 0.001

TABLE P-7 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG PUMP MODE, LENGTH, AND SURVIVAL OF STRIPED BASS COLLECTED AT THE BOWLINE POINT PLANT DISCHARGE INITIALLY AND 24 HOURS FOLLOWING ENTRAINMENT, 1975-1978

	df	G
Initial		
Length x pump mode independence	22	70.68**
Pump mode x survival independence	2	11.55**
2T vs. 3F x survival independence	1	0.52
2T+3F vs. 2F x survival independence	1	13.41
Length x survival independence	11	55.61**
6-8 mm x survival independence	2	4.92
9+ mm x survival independence	7	10.10
Length group x survival independence	2	45.73**
Pump mode x length x survival interaction	22	19.45
Pump mode x length x survival independence	57	158.94**
24 Hours (Non-normalized)		
Length x pump mode independence	22	70.68**
Pump mode x survival independence	2	22.35**
2F vs. 2T x survival independence	1	1.81
2 Pump vs. 3 Pump x survival independence	1	26.44**

Note: df = degrees of freedom
G = test statistic
** denotes $p<0.001$

TABLE P-7 (CONT.)

	df	G
24 Hours (Non-normalized) (Cont.)		
Length x survival independence	11	120.15**
5-6 mm x survival independence	1	0.12
7-8 mm x survival independence	1	0.18
9-13 mm x survival independence	4	4.20
14+ mm x survival independence	2	1.43
Length group x survival independence	3	119.01**
Pump mode x length x survival interaction	22	21.52
Pump mode x length x survival independence	57	234.70**

APPENDIX Q

SURVIVAL OF STRIPED BASS, WHITE PERCH, AND ATLANTIC TOMCOD DURING 96-HOUR LATENT EFFECTS OBSERVATIONS AT THE BOWLINE POINT PLANT, 1975-1979

TABLE Q-1 SURVIVAL BY LENGTH FOR STRIPED BASS DURING THE 96 HOURS FOLLOWING ENTRAINMENT AT THE BOWLINE POINT GENERATING STATION, 1975-1978

Length (mm)	Station	Total No. Collected	No. Alive							
			Initial	3 Hr.	6 Hr.	12 Hr.	24 Hr.	48 Hr.	72 Hr.	96 Hr.
4.0-4.9	D	4	1	1	1	1	1	0	0	0
	I	4	4	2	2	2	2	1	0	0
5.0-5.9	D	63	29	23	21	20	16	11	7	4
	I	21	15	13	13	11	11	9	8	6
6.0-6.9	D	215	111	86	73	66	61	53	44	34
	I	105	86	69	63	60	53	48	44	41
7.0-7.9	D	276	161	135	120	111	104	99	95	78
	I	134	111	90	81	77	72	70	64	59
8.0-8.9	D	175	108	90	80	75	69	68	64	56
	I	88	63	52	45	44	44	42	40	34
9.0-9.9	D	101	73	66	61	57	55	53	47	42
	I	34	26	25	23	23	23	23	22	18
10.0-10.9	D	119	76	65	63	61	58	54	51	46
	I	30	22	22	21	21	21	21	20	14
11.0-11.9	D	64	43	39	38	37	37	34	32	29
	I	23	21	19	18	18	18	18	17	17
12.0-12.9	D	61	44	40	39	36	36	36	35	34
	I	11	7	7	7	7	7	7	7	7
13.0-13.9	D	53	43	38	37	36	36	36	35	34
	I	6	5	4	4	4	4	4	4	4
14.0-14.9	D	41	30	28	28	28	28	28	27	24
	I	8	7	7	7	7	7	7	6	6
15.0-15.9	D	34	26	25	25	25	25	24	23	22
	I	7	5	5	5	5	5	5	5	4
16.0+	D	204	168	158	156	154	153	148	145	139
	I	33	32	32	32	32	32	32	32	30
All lengths	D	1,410	913	794	742	707	679	644	605	542
	I	504	404	347	321	311	299	287	269	240

TABLE Q-2 SURVIVAL BY LENGTH FOR WHITE PERCH DURING THE 96 HOURS FOLLOWING ENTRAINMENT AT THE BOWLINE POINT GENERATING STATION, 1975-1979

Length (mm)	Station	Total No. Collected	No. Alive Initial	3 Hr.	6 Hr.	12 Hr.	24 Hr.	48 Hr.	72 Hr.	96 Hr.
3.0-3.9	D	69	6	5	5	2	2	1	0	0
	I	48	5	5	5	5	3	2	0	0
4.0-4.9	D	219	27	20	12	9	5	5	3	1
	I	174	51	42	38	29	24	21	16	8
5.0-5.9	D	130	32	22	15	12	9	9	7	4
	I	112	51	41	36	33	26	23	16	9
6.0-6.9	D	70	20	10	8	7	7	6	5	5
	I	55	28	18	16	15	14	12	10	7
7.0-7.9	D	59	23	13	10	7	6	6	6	5
	I	36	15	12	9	7	7	6	5	4
8.0-8.9	D	33	18	10	9	9	9	9	8	7
	I	51	38	31	24	24	23	23	22	22
9.0-9.9	D	51	32	26	21	21	20	19	15	13
	I	39	32	25	21	16	15	15	14	13
10.0-10.9	D	35	22	14	14	14	14	14	13	10
	I	35	24	21	18	18	17	17	15	12
11.0-11.9	D	34	21	15	15	13	11	8	7	7
	I	28	20	19	18	17	16	15	14	13
12.0-12.9	D	25	23	19	17	12	12	12	12	10
	I	12	7	6	6	6	6	5	5	4
13.0-13.9	D	20	15	11	9	8	8	8	8	8
	I	9	8	8	7	7	7	7	7	7
14.0-14.9	D	17	13	11	11	10	10	9	9	9
	I	8	7	6	6	6	6	6	6	6
15.0+	D	23	16	13	8	8	8	8	8	8
	I	14	11	11	11	11	11	11	11	10
All lengths	D	785	268	189	154	132	121	114	101	87
	I	621	297	245	215	194	175	163	141	115

TABLE Q-3 SURVIVAL OF ALL LENGTH GROUPS OF ATLANTIC TOMCOD DURING THE 96 HOURS FOLLOWING ENTRAINMENT AT THE BOWLINE POINT GENERATING STATION, 1976-1977

	Total No.	No. Alive							
Station	Collected	Initial	3 Hr.	6 Hr.	12 Hr.	24 Hr.	48 Hr.	72 Hr.	96 Hr.
D	726	531	476	459	439	430	423	418	412
I	776	610	525	494	467	460	452	449	437

APPENDIX R

SUMMARY OF TRANSIT DURATION DATA FOR HATCHERY-REARED STRIPED BASS COLLECTED AT THE BOWLINE POINT PLANT DISCHARGE STANDPIPE DURING DIRECT-RELEASE STUDIES, 1979

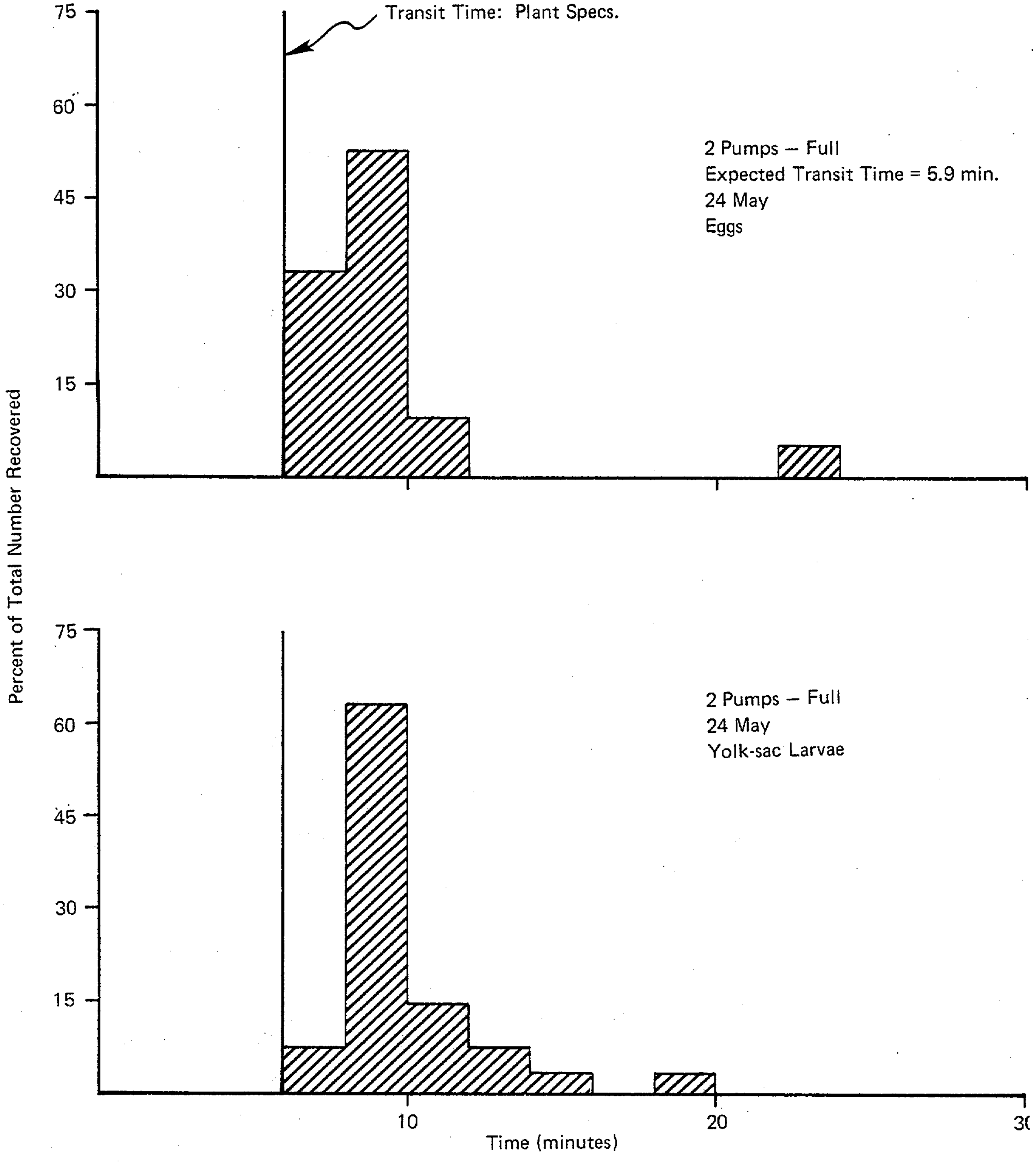

Figure R-1. Recovery of hatchery-reared striped bass larvae by 2 minute time intervals at the discharge standpipe (with manual nets) at the Bowline Point plant, May 1979.

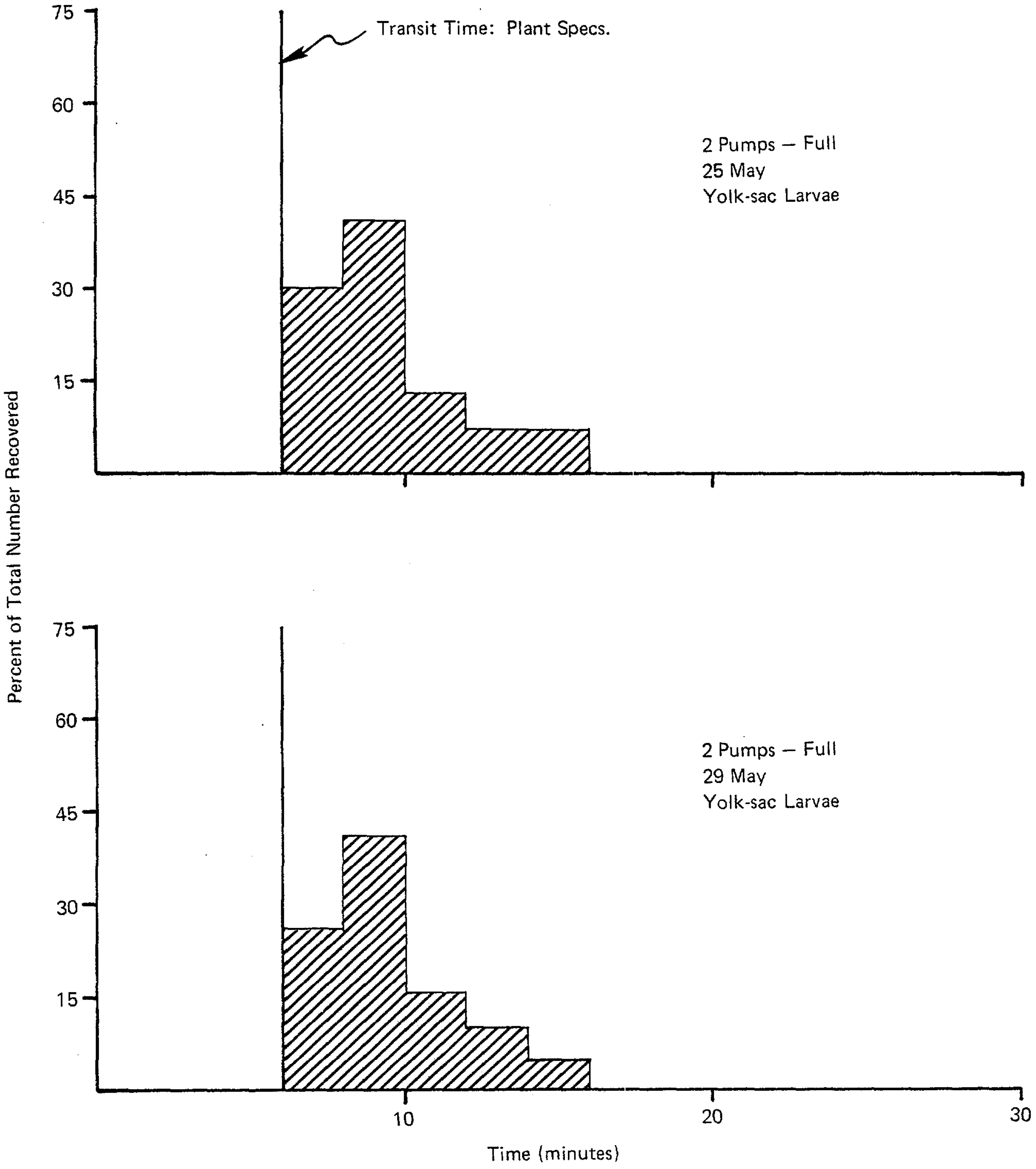

Figure R-2. Recovery of hatchery-reared striped bass larvae by 2 mintue time intervals at the discharge standpipe (with manual nets) at the Bowline Point plant, May 1979.

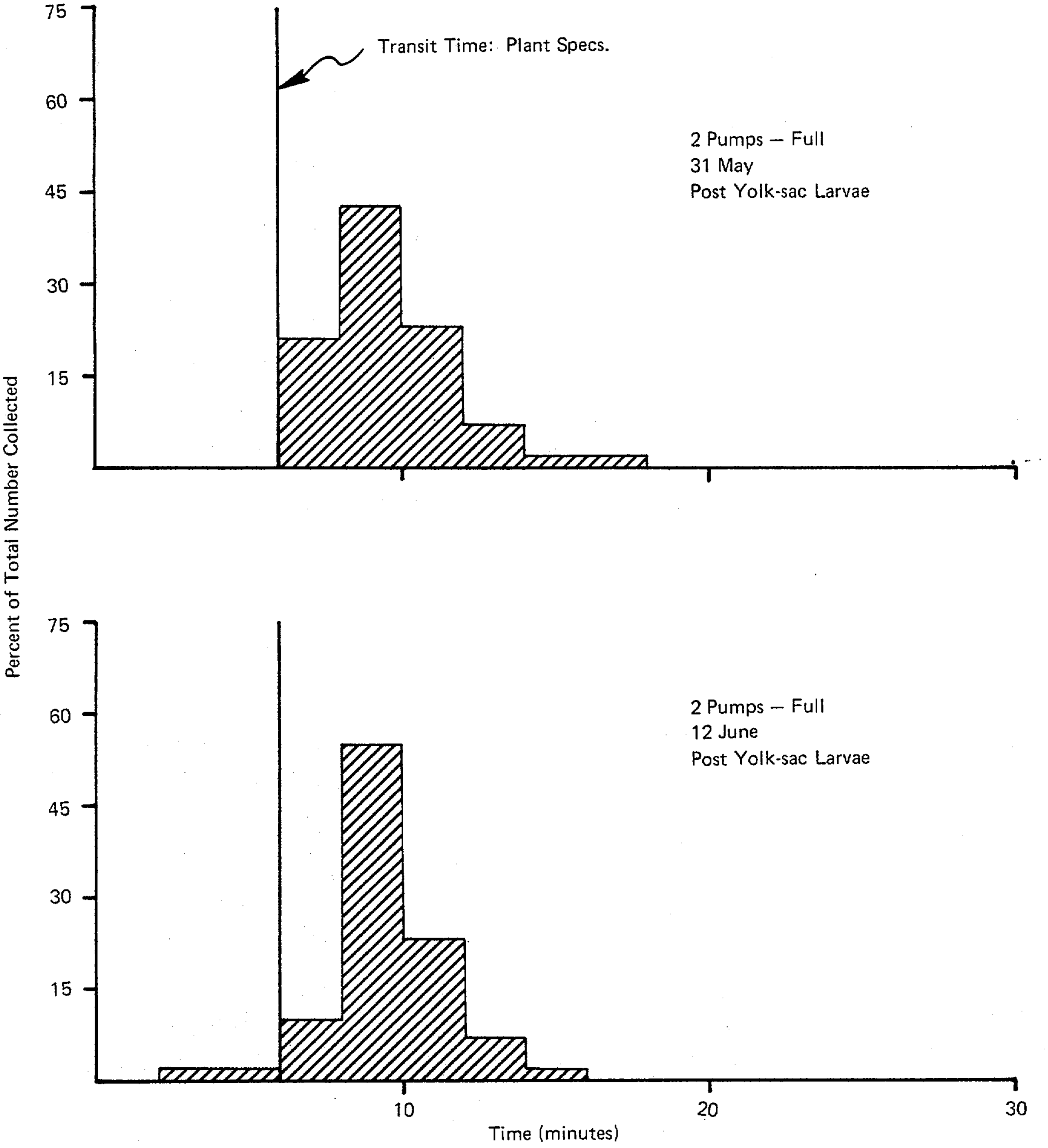

Figure R-3. Recovery of hatchery-reared striped bass larvae by 2 minute time intervals at the discharge standpipe (with manual nets) at the Bowline Point plant, May 1979.

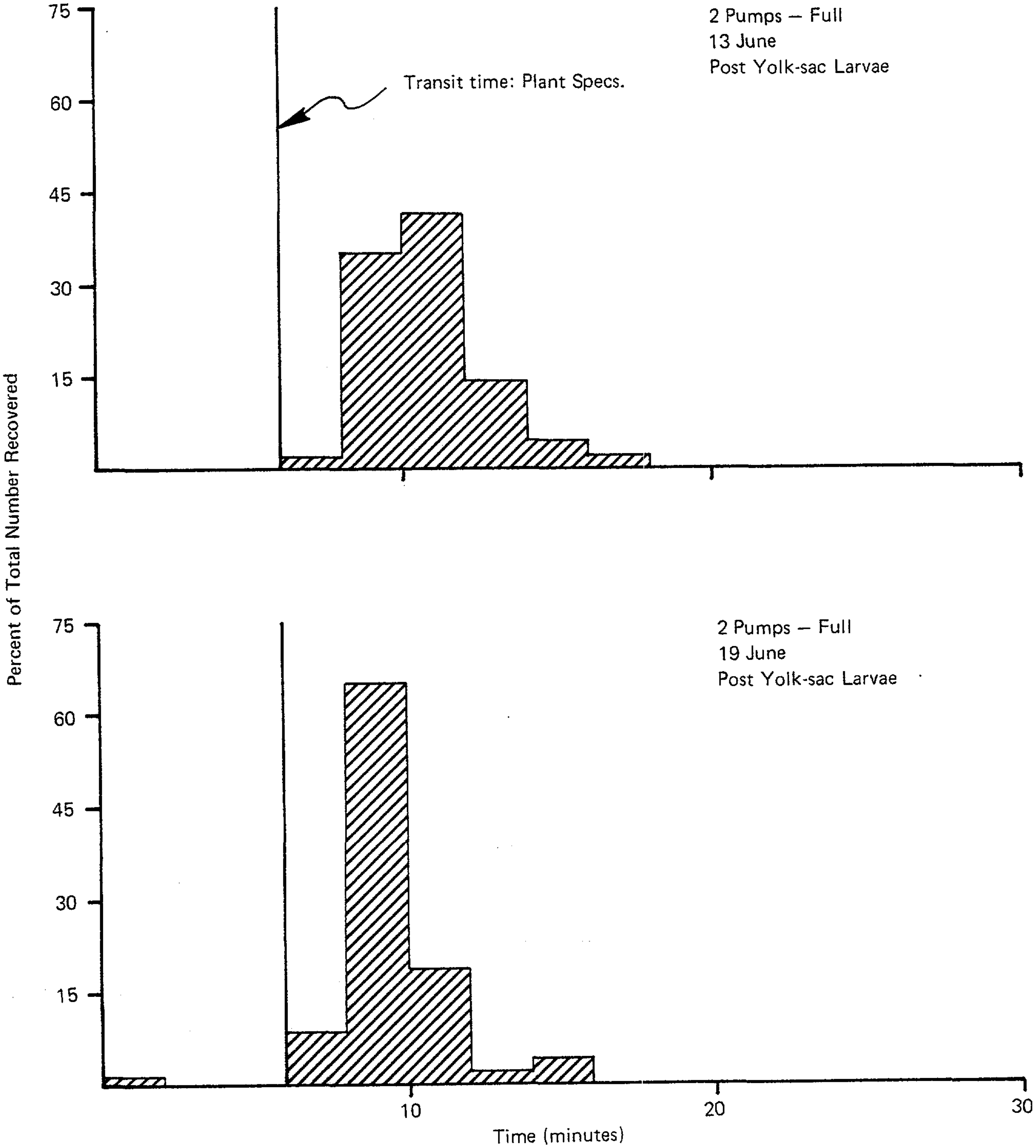

Figure R-4. Recovery of hatchery-reared striped bass larvae by 2 minute time intervals at the discharge standpipe (with manual nets) at the Bowline Point plant, May 1979.

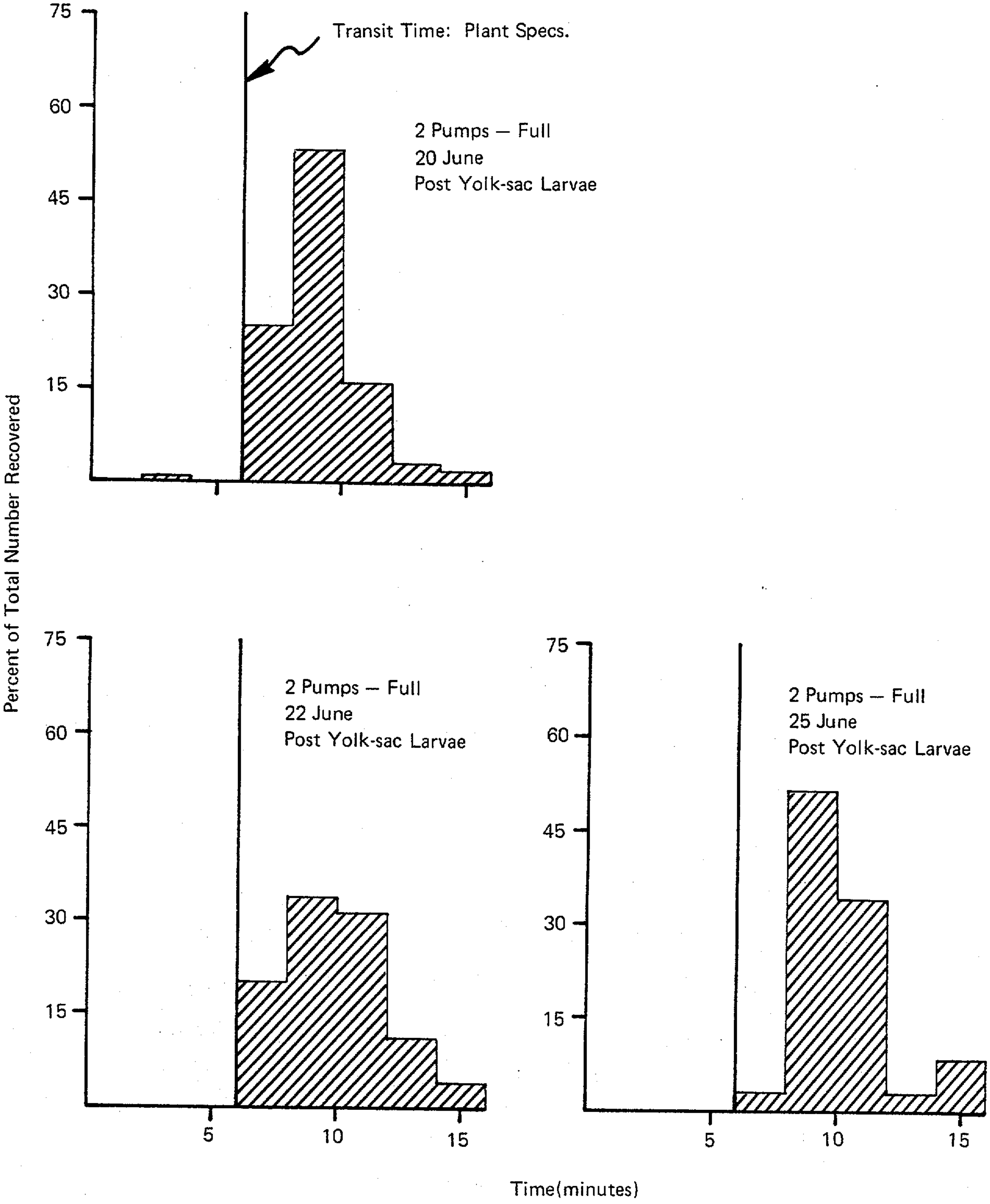

Figure R-5. Recovery of hatchery-reared striped bass larvae by 2 minute time intervals at the discharge standpipe (with manual nets) at the Bowline Point plant, May 1979.

Bowline Point Generating Station Entrainment Abundance and Impingement Survival Studies

1981 ANNUAL REPORT

Prepared Under Contract With:
Orange and Rockland Utilities, Inc.

Jointly Funded By:
Central Hudson Gas and Electric Corporation
Consolidated Edison Company of New York, Inc.
Niagara Mohawk Power Corporation
Orange and Rockland Utilities, Inc.
Power Authority of the State of New York

ECOLOGICAL ANALYSTS, INC.

EA Report ORU11K

1981 ANNUAL REPORT BOWLINE POINT GENERATING STATION ENTRAINMENT ABUNDANCE AND IMPINGEMENT SURVIVAL STUDIES

Prepared Under Contract With

Orange and Rockland Utilities, Inc.
One Blue Hill Plaza
Pearl River, New York 10965

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July 1982

CONTENTS

CONTENTS CONT.

1. INTRODUCTION

1.1 ENTRAINMENT

The objective of the 1981 entrainment abundance study was to determine the species composition, abundance, and density variations of selected ichthyoplankton entrained in the once-through cooling system of the Bowline Point Generating Station. Samples were collected using an automated abundance sampler located at an access point of the plant's cooling water discharge system. Sampling was performed twice per week from May through early September (primary spawning and nursery period for striped bass, white perch, bay anchovy, and clupeids), and was conducted continuously for 24 hours on each sampling day.

In this report, species composition and temporal patterns in abundance for the key taxa during 1981 are described and related to patterns in temperature and conductivity. Also included is a discussion of the effects of the plant outage dictated by the December 1980 Settlement Agreement on the overall numbers of organisms killed by entrainment. Overall, this 1981 entrainment abundance study represents a continuation of entrainment studies which have been conducted at the Bowline Point Generating Station every year since 1975.

1.2 IMPINGEMENT

Fishes impinged on power plant intake screens are potentially an important source of mortality associated with plant operations (Christensen et al. 1981 DeAngelis et al. 1977; Hanson et al. 1977; Jensen 1977, 1978; Van Winkle 1977; Van Winkle et al. 1978). King et al. (1978) showed that fish losses at several Hudson River plants could be mitigated by rotating and washing the traveling screens continuously and demonstrated that mortality increased as the time between screen rotation and washing increased.

Most other published studies dealing with fish impingement have addressed only estimates of the number of fish impinged (Grimes 1975; Mathur et al. 1977). In view of the lack of published information on survival of impinged fish, we designed and conducted studies at the Bowline Point Generating Station to assess this important factor. This study covers a six-year period and provides estimates of survival that characterize the range of values to be expected for various families and species found in the lower Hudson River estuary. The most abundant taxa of fish impinged at the Bowline Point plant, the primary subject of this study, are in the families Percichthyidae (striped bass and white perch), Clupeidae (American shad, alewife, and blueback herring) and Gadidae (Atlantic tomcod). Data for other species, collected incidentally with the major taxa, are limited, but have been summarized by family. The effect of water conductivity and temperature on survival of impinged fish will also be addressed.

Data presented in this paper are from collections that took place while the plant traveling screens were continuously rotated and washed, which is the operating mode demonstrated to maximize survival (King et al. 1978, EA 1979). Results from other operating modes are presented in King et al. (1978). More detailed review of data collected from 1975 to mid 1978 has been presented by EA (1979).

2. SITE DESCRIPTION

2.1 THE RIVER

The Bowline Point Generating Station is located on the west bank of the Hudson River estuary, approximately 37.5 miles upstream from the mouth of the river (Figure 2-1). This area of the Hudson River is commonly called Haverstraw Bay, and can be characterized as relatively shallow (average depth of 18 feet at mean low water) and wide (approximately 18,000 feet wide at the plant site).

Flow rates in the Hudson River near the Bowline Point Generating Station are controlled predominantly by the tides. The tidal flow has an average rate of 5,000 m^3/sec. Freshwater inflow into the Hudson River estuary provides a net downstream movement of water in the estuary; the freshwater discharge rate ranges from a monthly mean of about 175 m^3/sec during the summer dry period to 1,750 m^3/sec during spring high runoff period.

Condenser cooling water is withdrawn from a small embayment of the estuary known as Bowline Pond and returned directly to the Hudson River through an offshore jet diffuser (Figure 2-2). Bowline Pond has a surface area of 490,000 m^2 with a maximum depth of 12-15 m. Pond water exchanges with river water through a small inlet, 60-m wide with a maximum depth of 3-4 m.

Physicochemical variables, such as water temperature and conductivity, influence the temporal and spatial occurrence of ichthyoplankton, invertebrate zooplankton, and phytoplankton. The seasonal ambient river temperature profile in the vicinity of Bowline Point is typical of a temperate estuary. Daily water temperatures recorded at the Bowline Point plant intake reflect this pattern although they are occasionally influenced by recirculation of water from the discharge. Because of its physical connection with the estuary, the pond is also subject to salinity intrusion. Salinity of the Hudson River near the Bowline Point plant ranges from fresh water to approximately 8 ppt. Since the plant is located in the transitional portion of the estuary, conductivity is highly variable depending on freshwater flow and tidal mixing. Dissolved oxygen readings generally reflect the effect of seasonal ambient temperature variation on the solubility of oxygen in water. The pH is relatively stable and ranges from 6.0 to 8.4.

2.2 THE POWER PLANT

The Bowline Point plant consists of two completely enclosed oil- or gas-fired steam-electric units, each having a net generating capability rating of 600 MWe and a gross capability of 622 MWe (Table 2-1). Unit 1 began commercial operation in September 1972 and Unit 2 began commercial operation in May 1974.

Each unit has a separate once-through cooling water system. The cooling water is pumped from an intake structure located on Bowline Pond (Figure 2-2). Each intake bay is approximately 5-m (16-ft) wide and equipped with a bar trash rack, a 9.5-mm mesh vertical traveling screen, and a 700 m^3/min (185,000 gpm)

TABLE 2-1 PLANT DESIGN DATA FOR EACH UNIT OF THE BOWLINE POINT PLANT

Generator Characteristics	
Maximum generating capacity	620 MWe
Cooling water flow rate:	
Condenser (maximum)	23.7 m^3/sec (375,000 gpm)
Service	0.5 m^3/sec (8,500 gpm)
Intake Characteristics	
Maximum approach velocity to screens	0.23 m/sec (0.77 fps)
Pipe diameter from intake to condenser	3.2 m (10.5 ft)
Length of intake tunnel:	
Unit 1	400 m (1,310 ft)
Unit 2	470 m (1,540 ft)
Tunnel velocity (maximum)	3 m/sec (10 fps)
Discharge Characteristics	
Total length of discharge tunnel:	
Unit 1	860 m (2,820 ft)
Unit 2	875 m (2,870 ft)
Pipe diameter from condenser to discharge ports	3.2 m (10.5 ft)
Tunnel velocity (maximum)	3 m/sec (10 fps)
Length of diffuser	67 m (220 ft)
Number of diffuser ports	8
Initial jet velocity	4.6 m/sec (15 fps)

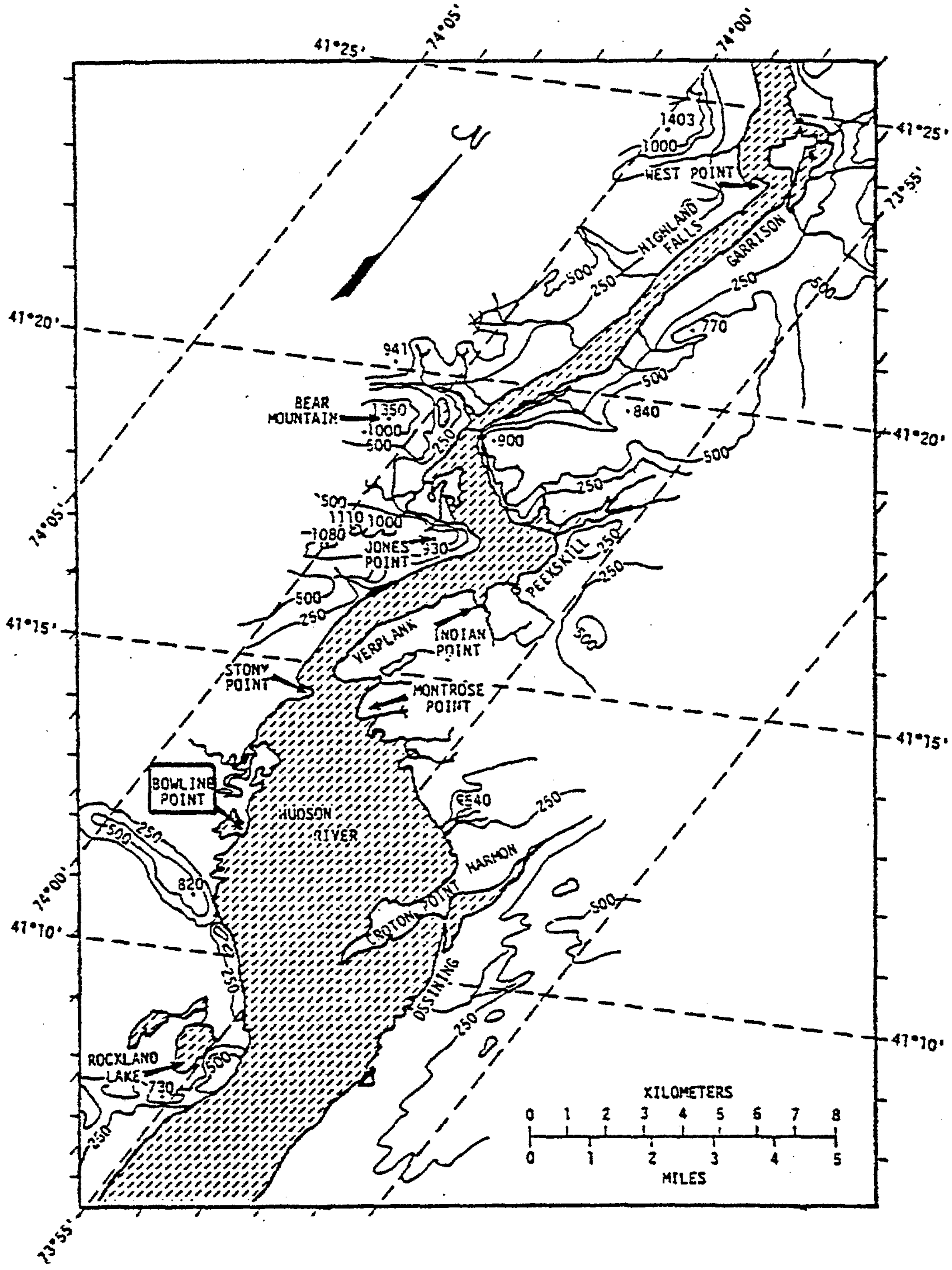


Figure 2-1. Hudson River estuary in the vicinity of the Bowline Point Generating Station (adapted from McFadden 1977:p. 2.6).

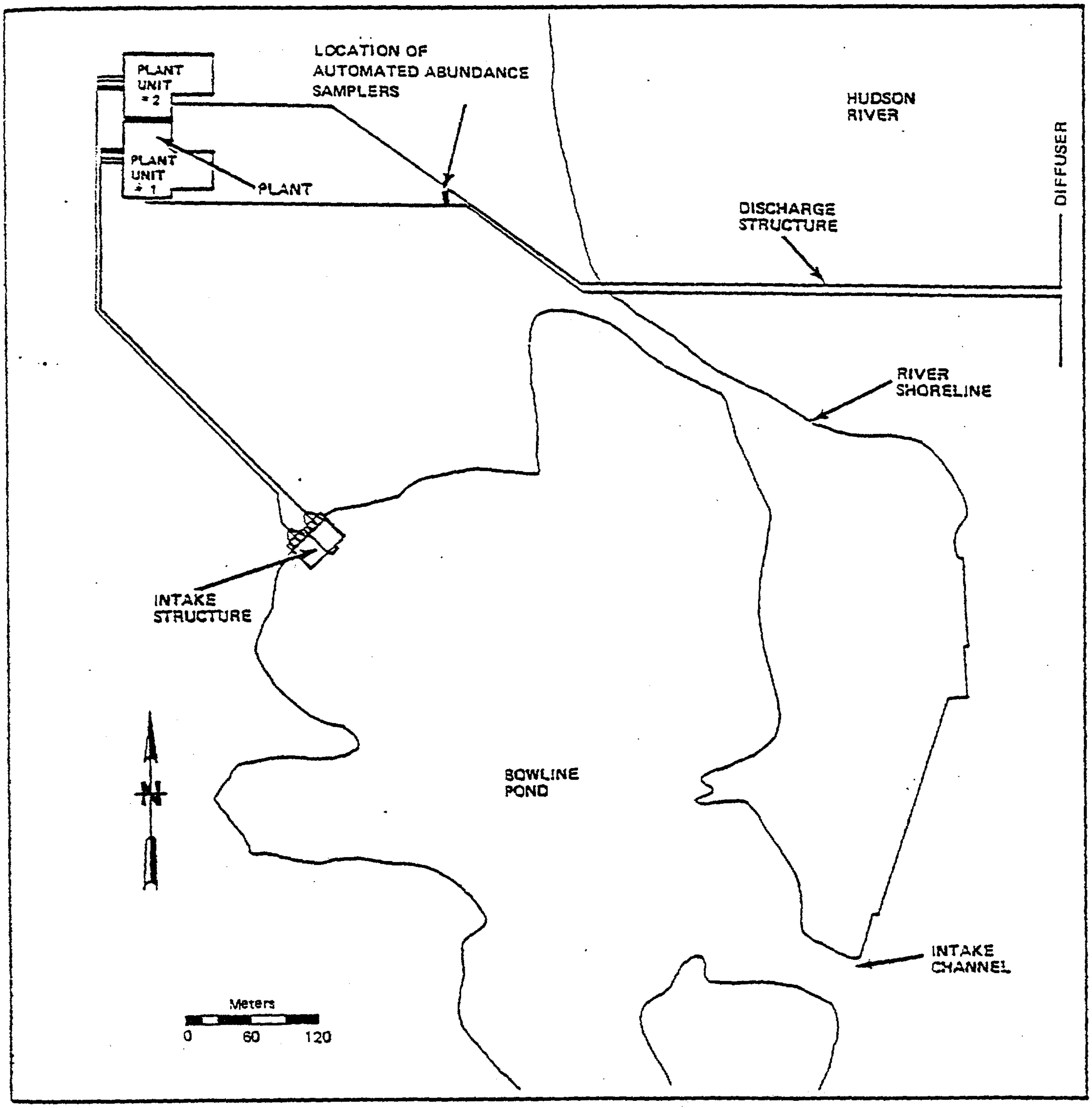


Figure 2-2. Diagram of Bowline Point plant site.

circulating water pump. The circulating water pumps for each unit can be operated individually or in combination. Circulating water flow and approach velocities at the bar racks vary with pumping mode:

Number of Pumps Operating	Total Flow at Mean Water Elevation m^3/sec (gpm)	Intake Approach Velocity m/sec (fps)
3	24.2 (384,000)	0.23 (0.77)
2	20.0 (316,000)	0.18 (0.59)
2 (throttled)	16.2 (257,000)	0.15 (0.49)

The units normally operate in one of three modes of pump operation: two pumps throttled (140 x 10^4 m^3/day), two pumps full (172 x 10^4 m^3/day), or three pumps full (209 x 10^4 m^3/day).

The circulating water is pumped through the condensers where the excess heat of the system is transferred to the cooling water. The maximum condenser cooling water flow is 24.2 m^3/sec (384,000 gpm). The circulating water is returned to the Hudson River about 400 m from the river shoreline where dispersion of the heated waters is effected by passage through submerged, multiport, high-velocity diffusers constructed perpendicular to the river flow.

2.3 TRAVELING SCREENS AND FISH COLLECTION SYSTEM

Fish and debris that pass through the bar racks and are impinged on the traveling screen are removed by a pressurized washwater system, rinsed into a sluiceway, and returned to Bowline Pond. The screens are typically rotated on an intermittent schedule with 4-hour hold between washes. Rotation and washing takes approximately 20 min. The traveling screens are equipped with low-pressure and high-pressure spray headers spaced 30 cm apart at the front near the upper end of the screen. As the traveling screens rotate, impinged fish and debris are first exposed to the low-pressure spray system operated at 0.7-2.74 kg/cm^2 (10-39 psi). Debris or fish that remain on the traveling screens are subsequently exposed to the high-pressure spray system operated at 2.81-4.22 kg/cm^2 (40-60 psi), to ensure maximum screen cleaning. The high-pressure system can also be operated independently. Prior to mid-1980 the washwater sluiceway sloped into the impingement collection pit where a baffle system retained large pieces of debris while organisms were returned to the pond through the screenwash discharge pipe (31 cm diameter) located along the northside of the intake structure. In mid 1980 the sluiceway was modified such that fish and debris flowed directly into the screenwash discharge pipe (51 cm diameter) which was extended to release fish approximately 43 m north of the intake structure and outside of the fish passage barrier net constructed around the intake.

The impingement collection pit was the primary collection area used for impingement survival studies until mid 1980. In order to retain impinged organisms, the collection pit was fitted with a 9.5-mm-bar-mesh steel basket. This basket provided support for the collection apparatus, which consisted of two knotless nylon bag nets (1.3-cm-bar mesh) suspended between two aluminum poles and a frame, which fit tightly into the steel mesh basket. Following the modification of the screenwash and discharge system collections were made from a raft mounted collection basket in Bowline Pond.

3. ENTRAINMENT ABUNDANCE

3.1 METHODS

3.1.1 Sample Collection Procedures

3.1.1.1 Sampling Procedures

Ichthyoplankton samples were collected at the Bowline Point Generating Station from May through early September 1981 (Table 3-1). Sampling was scheduled to occur twice per week, however, periodic gear malfunctions resulted in some variation from the schedule. Each sampling event consisted of a 24-hour continuous collection effort.

Samples were collected from the plant cooling water discharge pipe (Figure 2-2) using an automated abundance sampler (AUTOSAM; Figures 3-1 and 3-2). The basic components of the sampler include a 3-in. electric pump, a cylindrical collection tank (1 m in diameter and 1.2 m in height) containing a cylindrical 500-μm mesh plankton net, and a microcomputer control module. All components are housed in an enclosed trailer.

Operational sequences of the AUTOSAM are controlled by the microcomputer module. During sampling, water is pumped into the net in the collection tank where primary concentration of the sampled organisms and detritus occurs. Filtered water passes out of the collection tank through a discharge drain pipe. Flow rate and volume are measured by an inline flowmeter mounted to the pipe that transports water from the AUTOSAM sampling pump to the collection tank. At the end of the programmed sampling interval, the following automated operations occur: (1) the pump shuts off and the collection tank drains; (2) the collection net is rinsed, concentrating the sample into the bottom of the collection net; (3) the sample is washed into the secondary concentrator and then into a collection container using chilled water (4.4 C) to reduce organism decomposition; and (4) formalin is automatically injected into the collection container to achieve a 10 percent formalin to water solution. After each sample is collected, the turntable holding the collection containers rotates, and the sampling sequence automatically begins again.

Each sample can be comprised of many cycles; a cycle being defined as a sequence of pumping, net washdown, and transfer of sample contents to collection container. For the 1981 Entrainment Abundance Program at the Bowline Point Generating Station, each sample was a 24-hour composite, consisting of 24 one-hour cycles (specifically, each cycle consists of 57 minutes of sample collection and three minutes of net wash and sample transfer). Because of the relatively long sampling period (24 hours) for each sample, the normal operational sequence was modified to inject formalin into the collection container after each one-hour cycle to avoid potential cannibalization and decomposition. In addition, the collection of a 24-hour sample in one-hour cycles resulted in less damage to ichthyoplankton by reducing the times these organisms would be in the primary collection net.

All preserved samples collected via AUTOSAM were retrieved and transferred into sample jars with inside and outside inventory labels. All collection information (collection time, volume filtered, number of cycles, etc.) was obtained from the AUTOSAM memory and transferred onto data sheets.

TABLE 3-1 SAMPLING DATES, UNITS OPERATING, AND UNITS SAMPLED DURING THE 1981 ENTRAINMENT ABUNDANCE STUDY AT THE BOWLINE POINT GENERATING STATION

Sampling Date	Units Operating	Unit Sampled
12 MAY	1	1
14 MAY	1	1
17 MAY	1	1
21 MAY	1	1
24 MAY	1	1
28 MAY	1 and 2	1
31 MAY	1 and 2	1
4 JUN	1	1
7 JUN	1	1
26 JUN	2	2
27 JUN	2	2
29 JUN	2	2
30 JUN	2	2
7 JUL	1	1
9 JUL	1 and 2	1
11 JUL	1 and 2	1
12 JUL	1 and 2	1
14 JUL	1 and 2	1
15 JUL	1 and 2	1
16 JUL	1 and 2	1
24 JUL	1 and 2	2
30 JUL	1 and 2	2
1 AUG	2	2
2 AUG	2	2
14 AUg	1 and 2	2
15 AUG	1 and 2	2
24 AUG	1	1
25 AUG	1	1
27 AUG	1	1
2 SEP	1	1

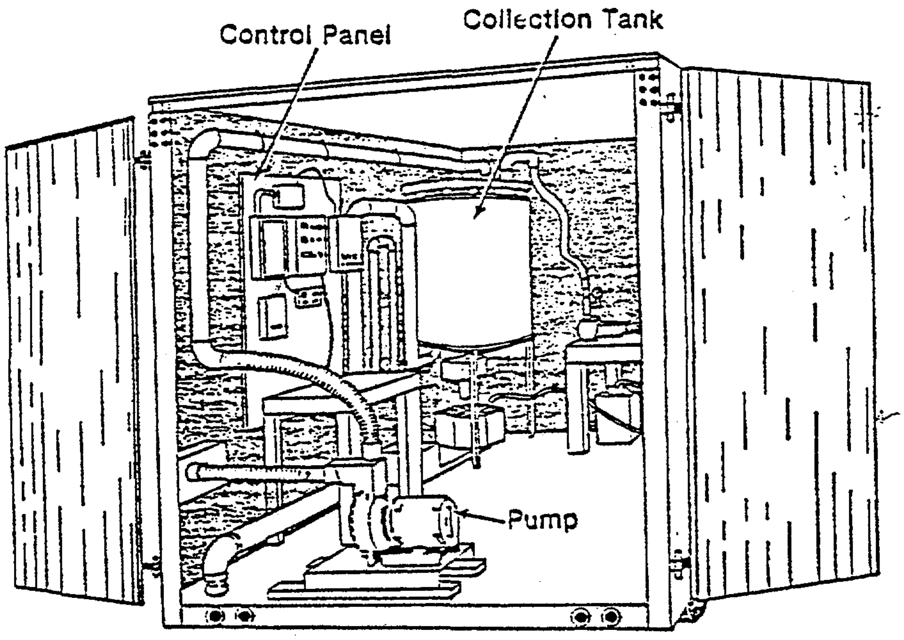


Figure 3-1. Interior of the portable automated abundance sampling system (AUTOSAM) housed in a trailer (U.S. Patent No. 4,145,928).

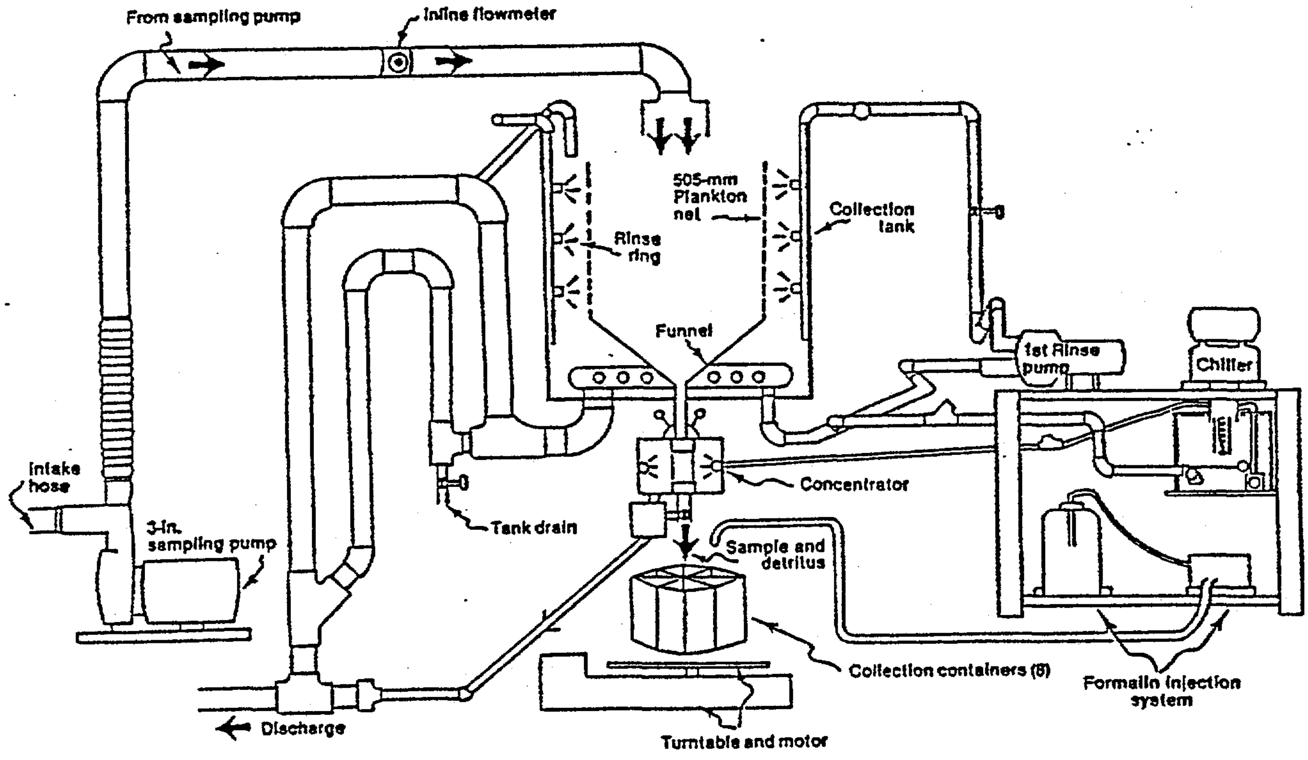


Figure 3-2. Schematic diagram of AUTOSAM.

3.1.1.2 Water Quality Measurements

Measurements of selected water quality parameters were conducted in conjunction with all sample collections. Temperature and conductivity were measured using a Martek water quality analyzer and strip chart recorder. Water quality measurement values were transferred onto sample data sheets during sample retrieval.

3.1.2 Laboratory Procedures

All preserved samples and data sheets were transported to EA's Central Laboratory in Middletown, New York. At the laboratory, ichthyoplankton were sorted from the preserved samples, identified to species and life stage, and counted. In addition, the total length of up to 25 larvae per taxon were recorded to the nearest 0.1 mm. All laboratory processing information was recorded on data sheets and transmitted to the EA Data Center for data entry and analysis.

3.1.3 Analytical Procedures

Entrainment abundance was examined for selected species or taxa groups. The abundances of these organisms are presented as either total numbers collected per sample or as a density determined as the ratio of the number of organisms in each sample to the volume of water sampled (number per 1,000 m^3).

Percentage composition for each taxon presented was determined as shown below:

$$\text{Percentage composition} = \frac{\text{Number for a given taxon}}{\text{Total number collected}} \times 100$$

Estimates of the number of each life stage cropped by entrainment under the various plant operating schedules were calculated from the weekly densities and daily plant flow and predicted entrainment survival as follows:

$$E_{c_i} = \bar{d}_i \sum_{j=1}^{7} (V_{ij} S_{eij})$$

where

E_{ci} = estimated number cropped by entrainment during week i

$\bar{d}_i$ = average density in entrainment abundance samples during week i

V_{ij} = daily unit flow for day j of week i

S_{eij} = predicted entrainment survival for day j of week i.

Actual unit flow was obtained from the plant operating log (Table C-1). Unit flows for the projected case of no outage was assumed to be equivalent to the higher actual flow from either operating unit. These projected flows consequently include some unscheduled outage and are thus often less than permitted flows. By setting the projected flows in this manner, it was felt that the most accurate indication of the true mitigation due to plant outage could be obtained.

The average weekly densities for each life stage of the four key species (Tables C-2 through C-5) were calculated by averaging the densities for all sampling days during each week. For those weeks in which no sampling occurred, the average weekly density was estimated by the geometric mean density of the two adjacent weeks. These average weekly densities were assumed to be the same for both units and under both actual and projected plant operating conditions.

For the two delicate groups, clupeids and bay anchovy, entrainment mortality was assumed to be 100 percent for all cases. Entrainment survival of striped bass and white perch was predicted using estimates of mechanical mortality and thermal mortality equations. Mechanical mortality estimates (Table C-6) were developed from actual field samples collected when discharge temperatures were less than those expected to induce thermal mortality. Thermal mortality rates for yolk-sac, post yolk-sac, and juvenile striped bass and white perch were predicted from thermal equations (Table C-7) taking into account ambient and discharge temperatures, transit time, and larval length. Ambient temperatures were assumed to be the same for both actual and projected cases whereas discharge temperatures for the projected case were set equal to the higher discharge temperature for either unit. Transit times for both the actual and projected cases were estimated from the corresponding unit flow rate for each operating condition. Finally larval length (Table C-8) was estimated by the median weekly length from the abundance samples. Lengths were assumed to be the same for both actual and projected cases, and estimates for weeks with no sampling were derived using linear interpolation of two adjacent weeks' values.

3.2 RESULTS AND DISCUSSION

3.2.1 Species Composition

Fifteen ichthyoplankton taxa, representing 12 families, were collected during entrainment abundance sampling at the Bowline Point Generating Station during 1981 (Table 3-2). The majority of ichthyoplankton collected were post yolk-sac larvae, which constituted 96.9 percent of the total catch (14,873 organisms collected) (Table 3-3). An additional 1.2 percent were eggs, 1.1 percent were juveniles and 0.1 percent were yolk-sac larvae.

The most abundant species collected during the 1981 abundance study was bay anchovy, representing over 88 percent of the total ichthyoplankton collected (Table 3-3). The other most abundant taxa (in order of decreasing abundance) were striped bass, white perch, and clupeids. These three taxa, along with bay anchovies, constituted over 96 percent of the total collection (Table 3-3). The taxonomic composition of ichthyoplankton collection in 1981 were similar to that observed during entrainment abundance studies conducted from 1975 through 1980 (EA 1981a, 1981b).

3.2.2 Seasonal Distribution And Abundance Of Key Species

The seasonal distribution of all species collected during 1981 was principally determined by the seasonal distribution of four dominant fish (striped bass, white perch, clupeids, and bay anchovy). Eggs were most abundant during

TABLE 3-3 NUMBER AND PERCENT COMPOSITION OF ICHTHYOPLANKTON COLLECTED DURING 1981 ENTRAINMENT ABUNDANCE STUDIES AT THE BOWLINE POINT GENERATING STATION

Taxon	Eggs Number Collected	Eggs %	Yolk-sac Larvae Number Collected	Yolk-sac Larvae %	Post Yolk-sac Larvae Number Collected	Post Yolk-sac Larvae %	Juvenile Number Collected	Juvenile %	Unidentified Life Stage Number Collected	Unidentified Life Stage %	Total Number Collected	Total %
Bay anchovy	29	0.2	0	--	13,072	87.9	99	0.6	6	<0.1	13,206	88.8
Striped bass	0	--	4	<0.1	454	3.1	12	0.1	0	--	470	3.2
White perch	146	1.0	0	--	254	1.7	11	0.1	0	--	411	2.8
Unidentified	1	<0.1	0	--	339	2.3	0	--	58	0.4	398	2.7
Herring	6	<0.1	0	--	90	0.6	19	0.1	0	--	115	0.8
Morone species	0	--	0	--	64	0.4	0	--	40	0.3	104	0.7
Sunfish	0	--	1	<0.1	46	0.3	0	--	0	--	47	0.3
Hogchoker	0	--	7	<0.1	36	0.2	0	--	0	--	43	0.3
Silverside	0	--	2	<0.1	35	0.2	1	<0.1	0	--	38	0.2
Northern pipefish	0	--	0	--	4	<0.1	11	0.1	0	--	15	0.1
Minnow and Carp	2	<0.1	0	--	6	<0.1	0	--	0	--	8	<0.1
Weakfish	0	--	0	--	3	<0.1	4	<0.1	0	--	7	<0.1
American eel	0	--	0	--	0	--	4	<0.1	0	--	4	<0.1
Perch	0	--	0	--	4	<0.1	0	--	0	--	4	<0.1
Atlantic tomcod	0	--	0	--	2	<0.1	1	<0.1	0	--	3	<0.1
TOTALS	184	1.2	14	0.1	14,409	96.9	162	1.1	104	0.7	14,873	100.0

TABLE 3-2 ICHTHYOPLANKTON PRESENT IN ENTRAINMENT ABUNDANCE SAMPLES AT THE BOWLINE POINT GENERATING STATION, 1981[(a)]

Family	Species Collected	
	Scientific Name	Common Name
Anguillidae	Anguilla rostrata	American eel
Clupeidae	Alosa spp. Alosa aestivalis Alosa sapidissima	Herring Blueback herring American shad
Engraulidae	Anchoa mitchilli	Bay anchovy
Cyprinidae(b)		Minnow and carp
Gadidae	Microgadus tomcod	Atlantic tomcod
Atherinidae	Menidia spp.	Silverside
Syngnathidae	Syngnathus fuscus	Northern pipefish
Percichthyidae	Morone spp. Morone americana Morone saxatilis	Temperate bass White perch Striped bass
Centrarchidae(b)		Sunfish
Percidae	Perca flavescens Etheostoma olmstedi	Yellow perch Tesselated darter
Sciaenidae	Cynoscion regalis	Weakfish
Soleidae	Trinectes maculatus	Hogchoker

(a) Reflects sampling from 10 May through 5 September 1981.
(b) No specimens were identified to a species level.

mid-May whereas the few yolk-sac larvae collected were more uniformly distributed throughout the sampling period (Figure 3-3). Post yolk-sac larvae were most abundant during July and August whereas juveniles reached peak abundance during August and early September.

Striped bass were first encountered as yolk-sac larvae during mid-May (Figure 3-4). No eggs were collected reflecting the location of Bowline south of the principal striped bass spawning area. Post yolk-sac larvae, the most frequently collected striped bass life stage, were most abundant the first half of June although densities continued relatively high through the end of June. During this period, ambient temperatures ranged from 22 to 25 C while average discharge temperatures ranged from 28 to 34 C. Striped bass juveniles were encountered only during late June and early July. The disappearance of striped bass juveniles from entrainment samples coincided with the rapid increase in salinity resulting from the upriver saltfront intrusion during early July.

The overall seasonal occurrence of white perch was similar to that of striped bass (Figure 3-5). White perch eggs were extremely abundant during the first sampling period in May, but decreased dramatically in abundance through mid-June. No yolk-sac larval white perch were collected suggesting that the normally adhesive eggs collected represented a dislodged or unfertilized portion not part of the successful spawn. Post yolk-sac larval white perch were most abundant during the second week in June; a pattern similar to that of striped bass. The seasonal abundance pattern for the juvenile stage was virtually identical to that of striped bass.

Clupeid eggs were encountered only during the first sampling period in May whereas no yolk-sac larvae were collected at all (Figure 3-6). Peak abundance of clupeid post yolk-sac larvae was from mid- to late May with declining abundance extending through mid-June. Juveniles were collected during July and again in mid-August. Catches of juveniles were restricted to periods of increased salinity, after the summer saltfront intrusion.

The eggs of bay anchovy, a summer-spawning marine species, were collected only during one week in mid-July 1981 (Figure 3-7). No bay anchovy yolk-sac larvae were collected during 1981 reflecting a combination of the extremely short life stage duration (12-18 hours), low abundance, and small size permitting potential extrusion through the normal 505 μm mesh sampling gear. Post yolk-sac larval anchovies were extremely abundant in the entrainment samples from late June through the end of August with peak densities occurring from mid-July through early August. Juvenile anchovies were most abundant during early August and again in early September following the period of peak larval occurrence.

Overall, the seasonal pattern of egg, larval, and early juvenile occurrence for the key fish species in Bowline entrainment sampling was similar to that reported for previous years, 1975-1980 (EA 1981, 1981b). While the overall pattern of occurrence remains similar across years, the actual number of

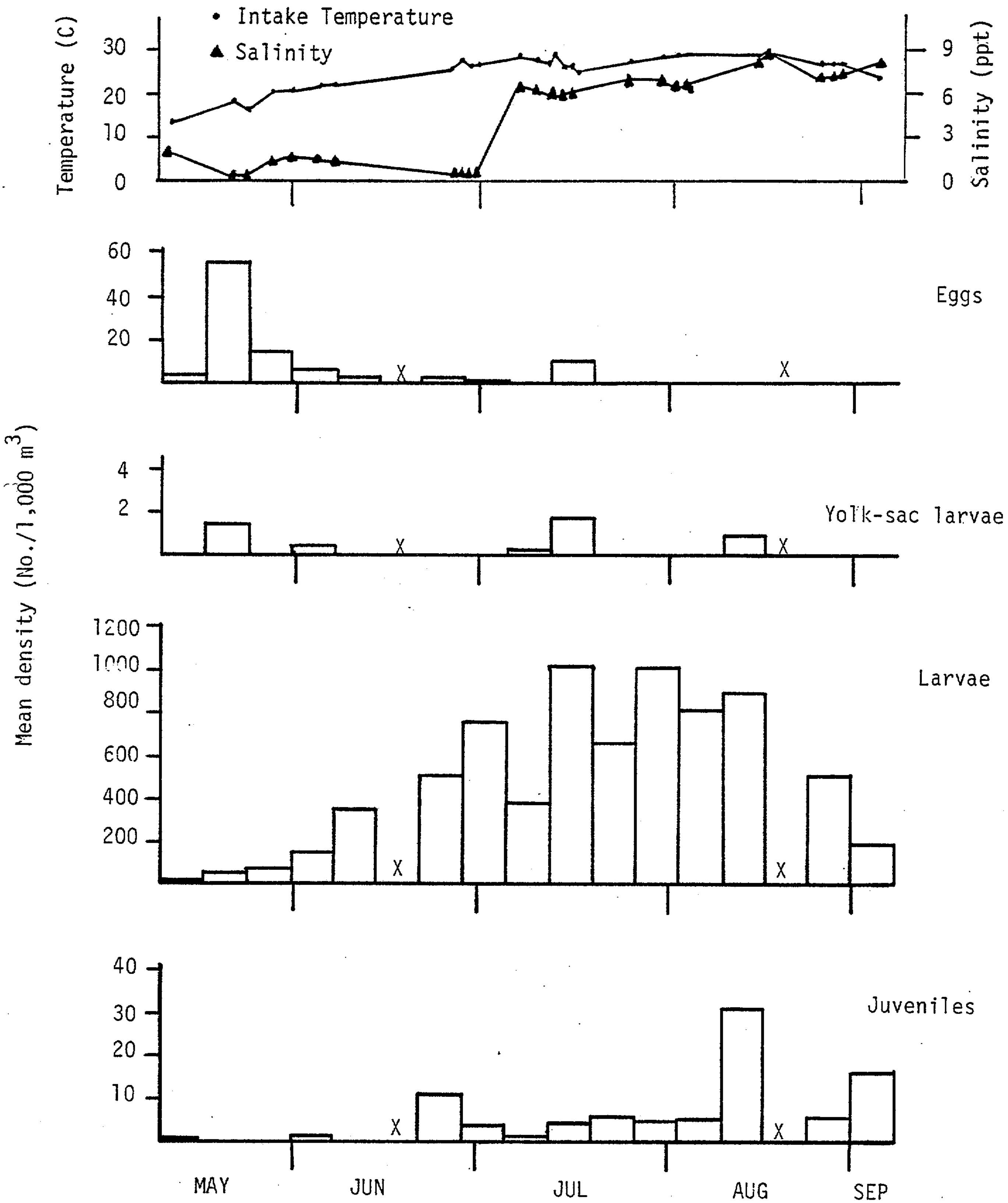


Figure 3-3 Mean densities (No./1,000 m^3) of ichthyoplankton early developmental stages collected during the entrainment abundance study, Bowline Point Generating Station, 1981.

X No sampling.

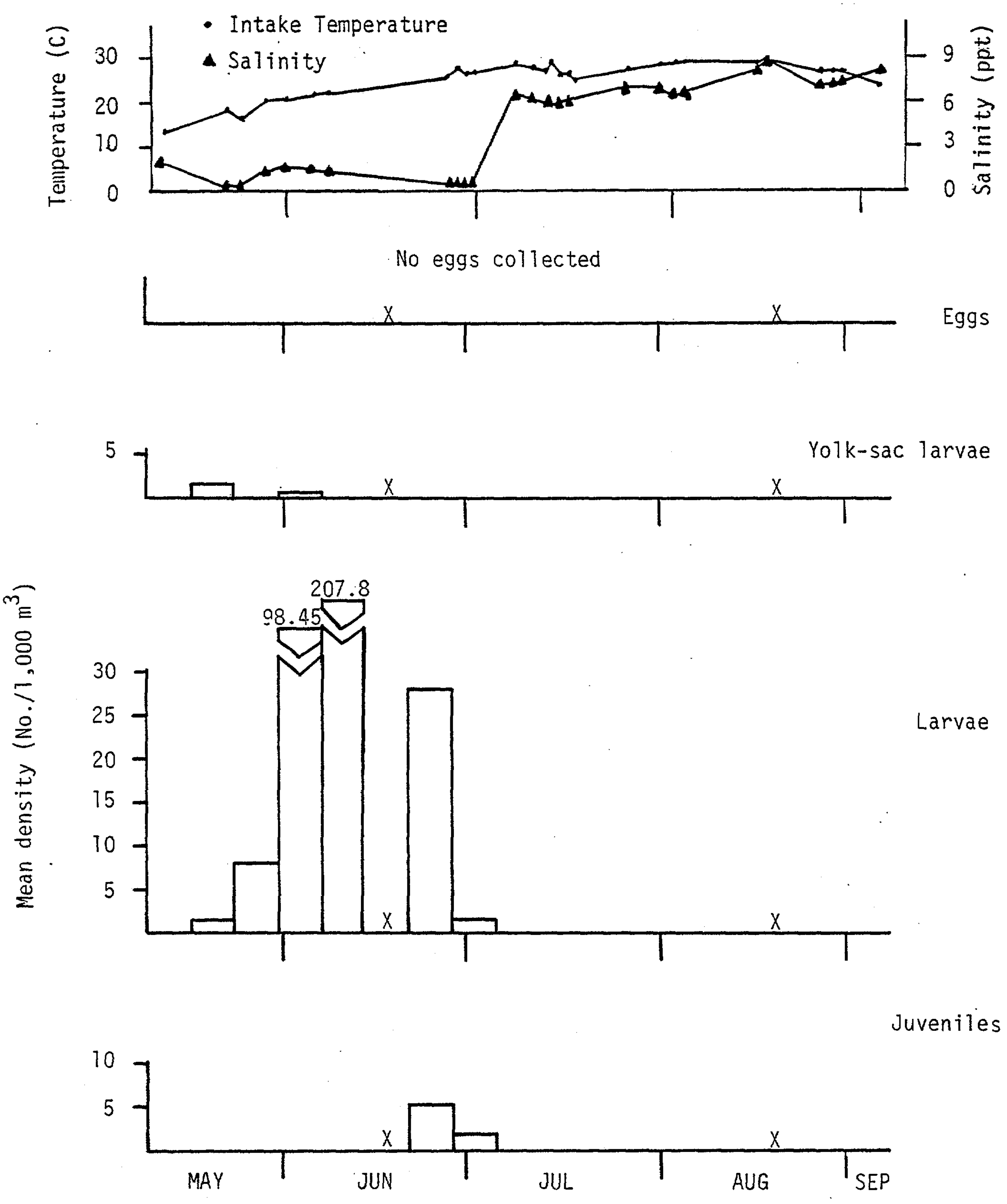


Figure 3-4 Mean densities (No./1,000 m^3) of striped bass early developmental stages collected during the entrainment abundance study, Bowline Point Generating Station, 1981.

X No sampling.

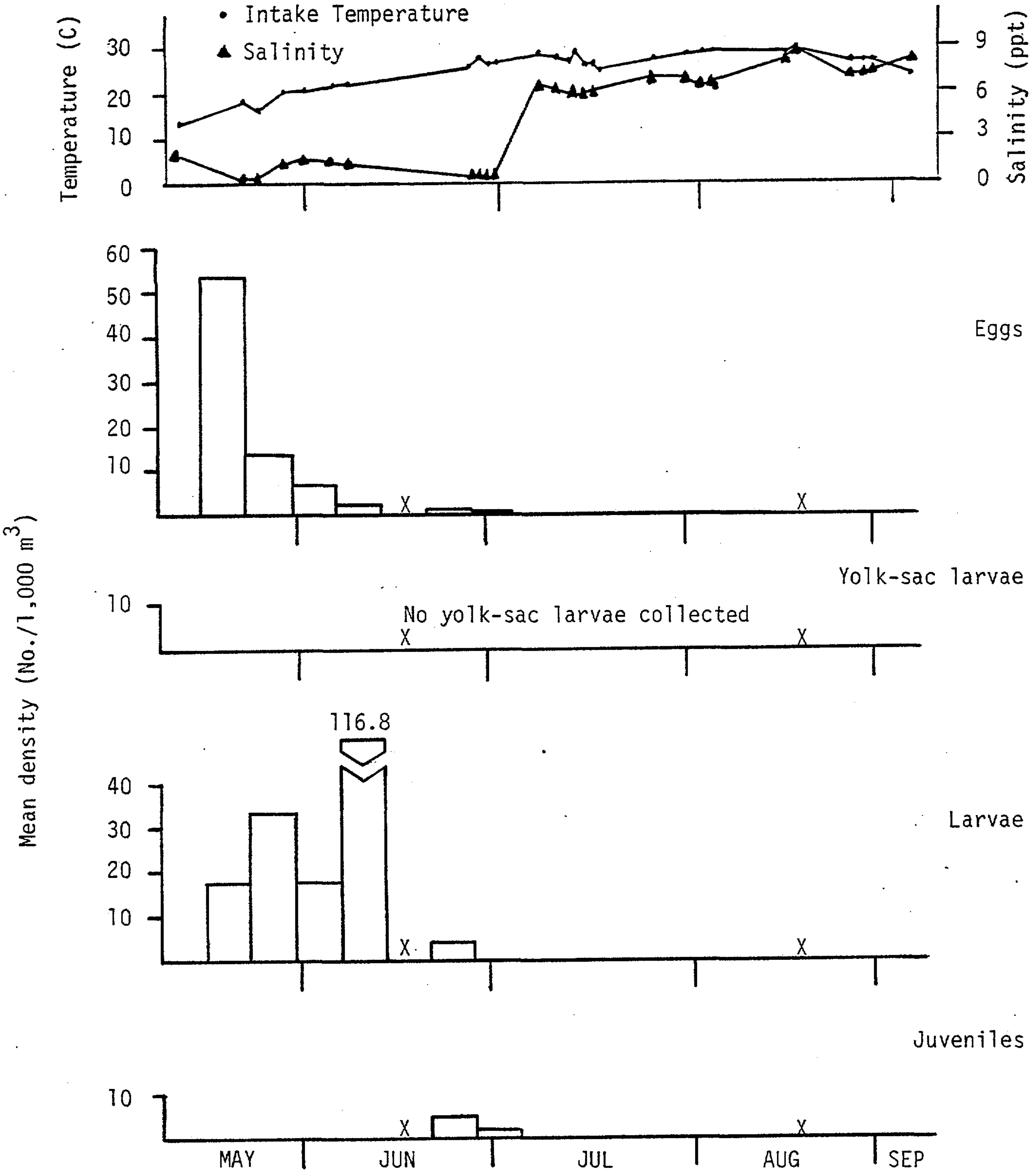


Figure 3-5. Mean densities (No./1,000 m^3) of white perch early developmental stages collected during the entrainment abundance study, Bowline Point Generating Station, 1981.

X No sampling.

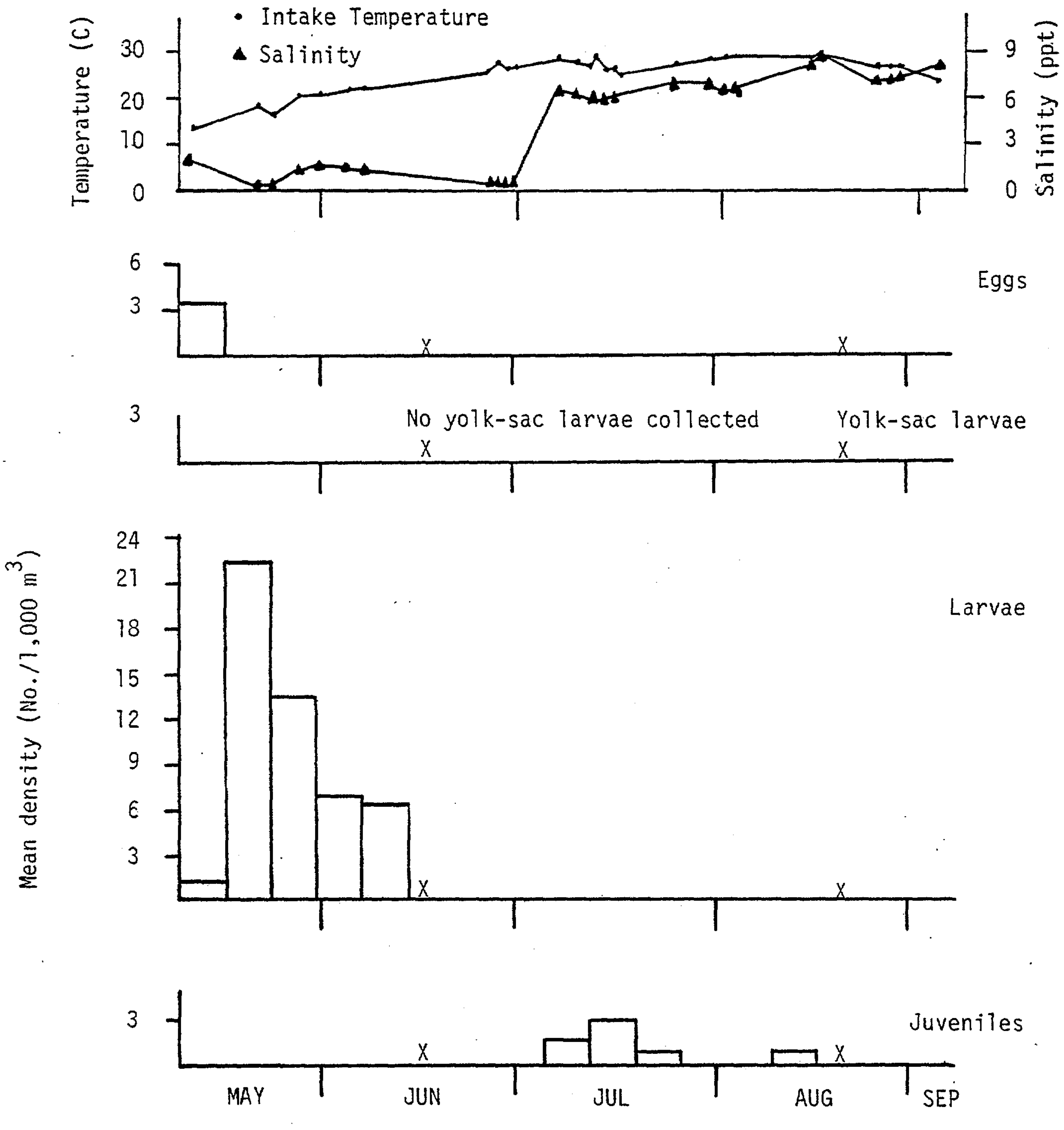


Figure 3-6. Mean densities (No./1,000 m^3) of clupeids early developmental stages collected during the entrainment abundance study, Bowline Point Generating Station, 1981.

X No sampling.

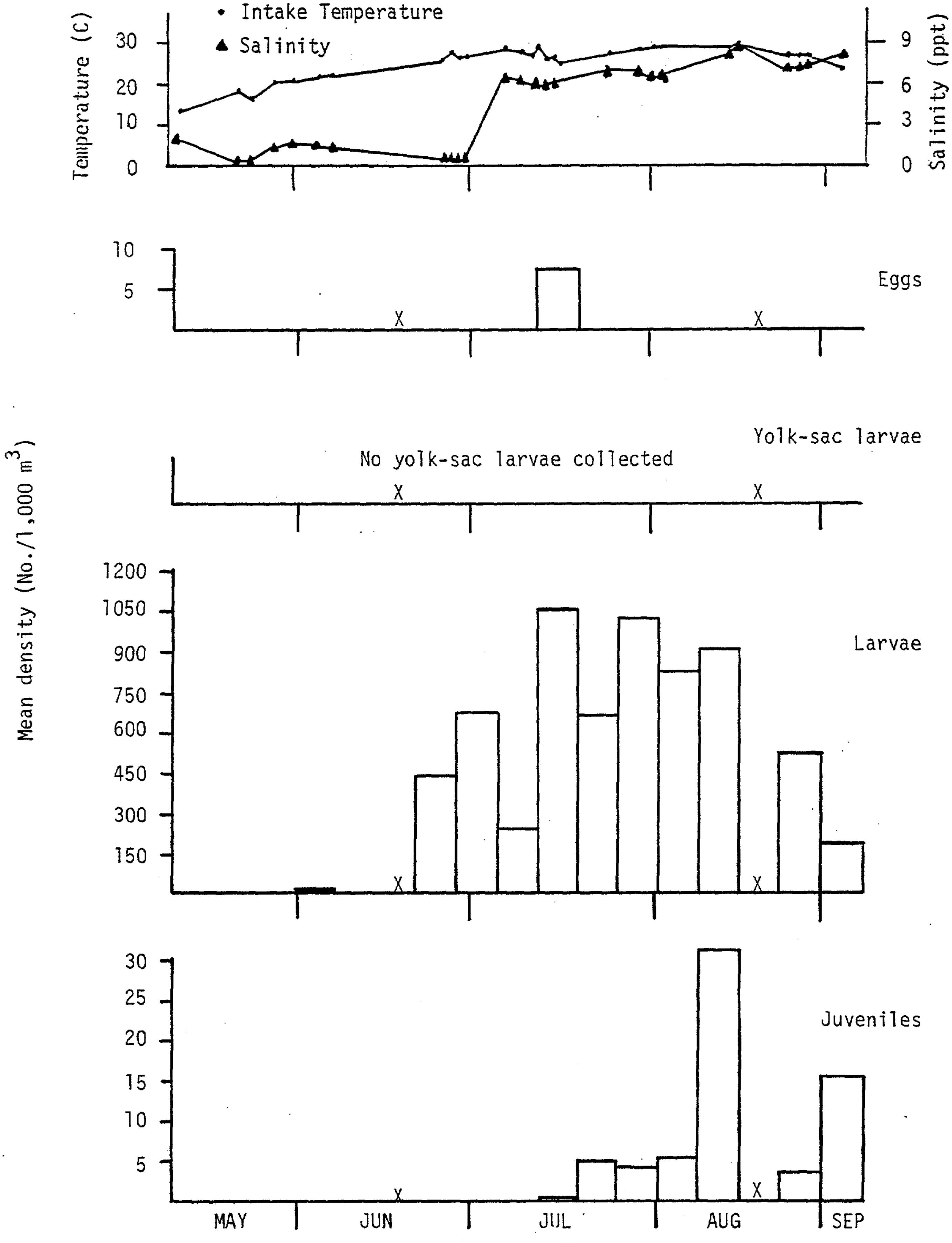


Figure 3-7. Mean densities (No./1,000 m^3) of bay anchovies early development stages collected during the entrainment abundance study, Bowline Point Generating Station, 1981

XNo sampling.

organisms entrained can fluctuate widely from one year to the next. This wide fluctuation results from differences in distribution and movements as well as growth and development rates for each population, all of which are influenced by numerous environmental factors particularly temperature and freshwater flow. As yet, the factors related to these changes in vulnerability are not well known enough to permit accurate prediction of the number of individuals cropped by entrainment in the cooling water flow at Bowline.

3.2.3 Effects Of Plant Outage On Entrainment Impact

The Settlement Agreement of December 1980 among the Hudson River Utilities, the EPA, the NYSDEC, and various other parties called for the scheduled outage of units at several Hudson River plants during periods of peak entrainment. Although the actual schedule can be quite complex due to cross-plant credits for excess outage, the basic plan calls for Bowline circulating water pumps to be out of operation for 30 days at either unit between 15 May and 30 June and for 31 days at either unit in the month of July in each year. The earlier outage is presumably to protect the younger stages of striped bass, white perch, and clupeids whereas the later outage would afford greatest protection to bay anchovy and the older stages of the three previously mentioned species.

The purpose of this section is to evaluate the effects of the actual plant outage on entrainment impact during the period 10 May - 5 September 1981 on the four key species: striped bass, white perch, clupeids (predominantly alewife and blueback herring), and bay anchovy. This evaluation will involve a comparison of the estimated number of eggs, larvae, and early juveniles actually cropped during 1981 to the projected number cropped assuming a continuous (non-outage) operation schedule. This measure of entrainment impact should not be construed as a measure of the effects of entrainment on any population as a whole, however, it does serve as a useful starting point for the assessment of various mitigation procedures.

Throughout the entire period of entrainment abundance sampling in 1981 (10 May - 5 September), Bowline pumping rates were approximately one-third less than the flow projected to have occurred under non-settlement operation. Most of this reduction occurred during the months of May and June although some reduction also occurred during August (Figure 3-8). During most of July, the plant operated at or near the projected values.

For all life stages of striped bass and white perch, reductions in the estimated number of individuals cropped by entrainment approached or more commonly exceeded 40 percent (Table 3-4). The lowest reduction being 38 percent for white perch post yolk-sac larvae and the highest being more than 50 percent for striped bass juveniles. Reductions were similarly high for all life stages of clupeids except the juveniles. Bay anchovy experienced considerably lower reductions ranging from 0 percent for eggs to slightly more than 27 percent for post yolk-sac larvae.

Differences in the estimated percent reductions among species and life stages are undoubtedly due to the interaction between the temporal occurrence of individuals in Bowline cooling waters and the temporal pattern in total flow

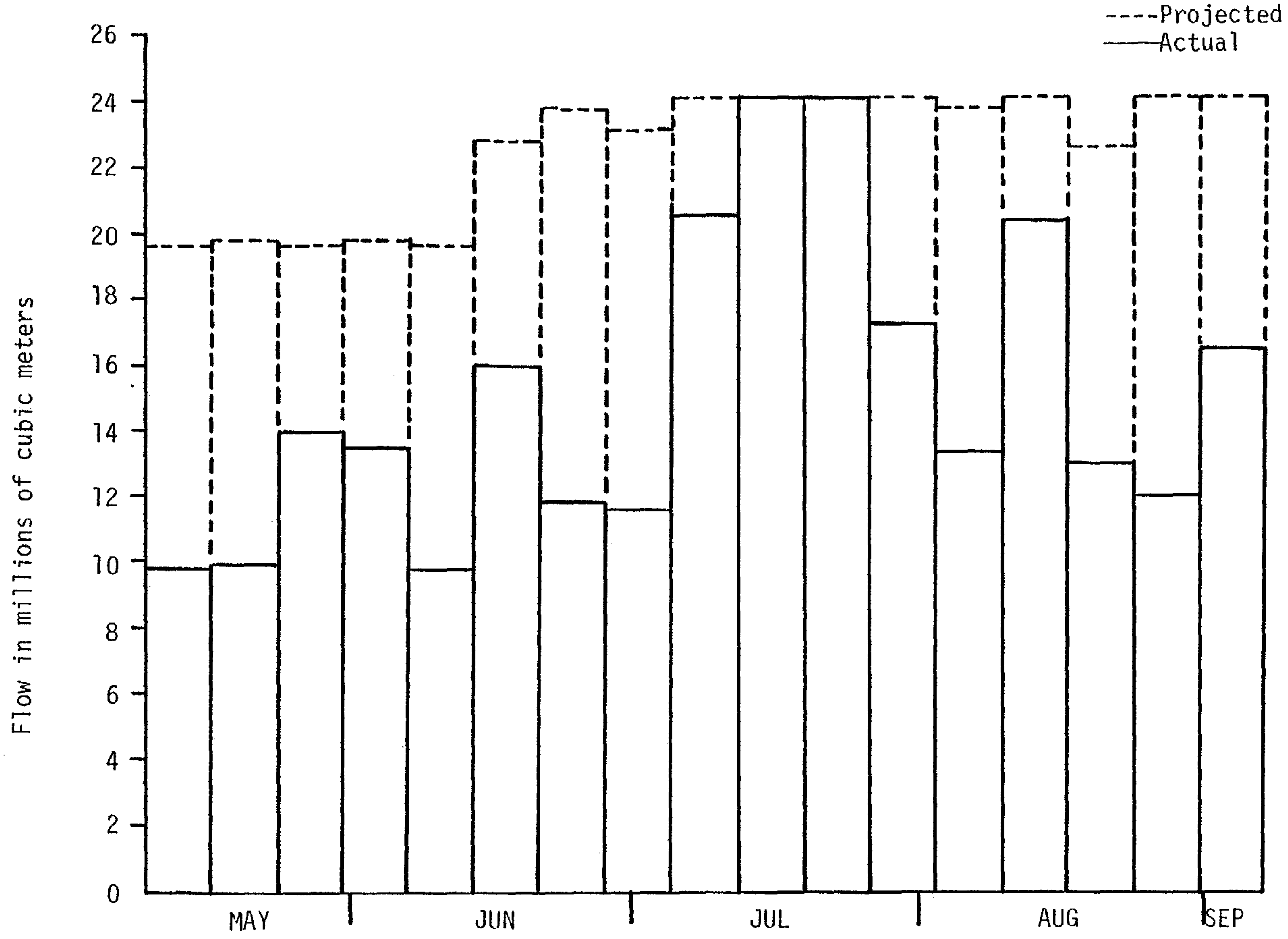


Figure 3-8 Temporal pattern in the weekly plant flow under both actual and projected condition at Bowline during 1981.

TABLE 3-4 ESTIMATES OF THE NUMBER CROPPED BY ENTRAINMENT FOR FOUR KEY SPECIES AND TOTAL SYSTEM FLOW FOR THE ACTUAL AND PROJECTED MODES OF OPERATION AT BOWLINE, 1981

Species	Life Stage	Estimated Numbers Projected	Estimated Numbers Actual	Percent Reduction
Striped bass	Eggs	-------------none	collected------------	
	Yolk-sac larvae	5,077	2,791	45.0
	Post yolk-sac larvae	1,204,837	680,035	43.6
	Early juveniles	37,535	18,228	51.4
White perch	Eggs	187,955	103,637	44.9
	Yolk-sac larvae	-------------none	collected------------	
	Post yolk-sac larvae	394,833	243,384	38.4
	Early juveniles	53,511	29,192	45.4
Clupeids	Eggs	62,759	31,379	50.0
	Yolk-sac larvae	-------------none	collected------------	
	Post yolk-sac larvae	1,029,257	604,396	41.3
	Early juveniles	127,806	119,517	6.5
Bay anchovy	Eggs	176,036	176,036	0
	Yolk-sac larvae	-------------none	collected------------	
	Post yolk-sac larvae	173,355,453	125,845,942	27.4
	Early juveniles	1,770,159	1,315,403	25.7
Total Flow		$383.3 \times 10^6 m^3$	$257.8 \times 10^6 m^3$	32.7

reduction. Striped bass, white perch, and the egg and larval stages of the clupeids exhibited relatively high reductions since they typically occur during May and June when flow reductions were highest. For clupeid juveniles and bay anchovy, reductions were much lower since they occur primarily during July and August when the plant operated at much closer to projected conditions.

Clearly, the results of this analysis indicate that, at least for Bowline during 1981, the scheduled outage accomplished exactly what it was designed to do; that is, reduce the number of individuals of key fish species cropped by entrainment. However, while the number of individuals cropped by entrainment as presented in this report is an easily calculated and relatively precise measure of power plant impact compared to estimates based on river sampling, it should not be construed as an indication of the effects of power plant operation on the abundance or persistence of the entire stock for any fish species. Estimation of these effects is exceedingly difficult requiring information on the complex behavior and dynamics of the population under a wide variety of conditions. In lieu of this detail, the numbers cropped at least provides a quantifiable index of the effects of this mitigative measure.

CHAPTER 4: IMPINGEMENT SURVIVAL

4.1 METHODS

4.1.1 Impinged and Control Fish

Impinged fish from 1975 to mid 1980 were sampled with a 1.27 cm knotless nylon mesh basket (193 x 97 x 61 cm) suspended between aluminum poles in a collection pit located inside the plant intake building. Fish and debris washed from the 0.95 cm mesh traveling screens entered a sluiceway which carried the material to the collection pit. Water was returned to the river through a 31 cm pipe which discharged in close proximity to the intake structure. During collection, the basket was kept immersed in water to minimize stress on the collected fish. From 1975 through June 1978 collections were taken for periods of 15 to 30 minutes during continuous rotation and washing of the conventional traveling screens; after June 1978 collection duration was shortened to five minutes in order to reduce collection stress.

In July 1980, the screenwash discharge pipe was replaced with a 51 cm pipe and the discharge location moved to a point 43 m from the intake structure. Extensive changes were also made to the screenwash sluiceway, which eliminated the collection pit, and necessitated the construction of a new sampling apparatus at the point of discharge. The apparatus consisted of a 3.9 m x 6.7 m raft with a 111 x 107 x 150 cm deep sampling basket (1.27 cm mesh) located in the center. A 7.3 m long chute carried discharge water from the pipe into the sample basket.

During the studies from 1975 to mid 1978, control fish, used to assess mortality fom collection and holding were collected from the Hudson River by beach seine or otter trawl at least five days prior to testing. Fish were immediately transfered to the holding facility and were fed daily rations of brine shrimp and a commercial trout feed. Striped bass and white perch control fish were exposed to the impingement collection basket and screenwash for time periods of 0, 1, 15, 20, and 30 minutes in order to assess the effect of collection duration on survival (EA 1979).

From mid 1978 to 1981, control fish were added to the collection gear at one-minute intervals, throughout a five-minute collection period assuming that impinged fish enter the collection apparatus at a constant rate during collection. Equal numbers of fish were added at each of six intervals during testing.

4.1.2 Holding Facility

After collection, impinged and control fish were immediately sorted and classified as to survival condition. All live fish (able to maintain equilibrium and swim normally) and stunned fish (unable to maintain equilibrium) were enumerated, identified, and transferred to an ambient water flow-through facility. Dead fish were enumerated and identified. During 1975 through mid 1980, fish were removed from the collection basket and placed in 60 x 45 x 30 cm deep containers for transport to the holding facility. For studies from mid 1980 through 1981, six removable transport containers (36 x 56 x 30 cm deep) were incorporated into the collection basket design which eliminated the above handling step.

After collection fish were placed in 189 ℓ holding tanks. Each tank held up to 20 to 24 small fish (young of the year) or 5 to 15 larger fish (yearling and adult).

Survival was observed for a period of 96-108 hours after collection. Fish were not fed during this extended survival observation period.

4.1.3 Data Analysis

Percentage survival was calculated as follows: (1) initial survival = [(number initially live + stunned) ÷ (number initially live + stunned + dead)] x 100; and (2) extended survival = [(number live and stunned at 96-108 hours) ÷ (number initially live + stunned + dead)] x 100.

To distinguish mortality which resulted from the stress of impingement and mortality from collection and observation, it was necessary to use the survival of control fish to adjust survival of fish collected from the intake screens. Since field observations support the assumption that impinged fish enter the collection net at a constant rate throughout the 5 or 30 minute collection periods, the average exposure duration for the fish in the collection net was 2.5 or 15 minutes. For white perch and striped bass collected from 1975 to 1978, control fish were placed in the collection basket and exposed for discrete durations between 0 and 30 minutes. The average collection and observation effect was calculated by pooling fish for each exposure period and making a discrete estimate of initial and extended survival. An unweighted average of these individual estimates was used as the estimate of control survival.

For control data collected from 1978 to 1981 in which equal numbers of fish were added at equal intervals throughout the control test, the survival data represent the average exposure case.

Survival of fish for which control data were available was adjusted for mortality associated with collection, handling, and holding, assuming that the effect of these sources of stress were additive:

$$S_i = \frac{P_e}{P_c}$$

where:

S_i = proportion surviving impingement.
P_e = proportion of impinged fish surviving.
P_c = control proportion surviving.

The standard error (S.E.) of S_i was calculated in accordance with the following equation (Fleiss 1973):

$$S.E. = \frac{1}{P_c}\left[\frac{P_e\,(1-P_e)}{N_e} + S_i^{\,2}\ \mathrm{Var}\,(P_c)\right]^{1/2}$$

Although this equation depicts the binomial vaiance of the survival estimate, it does not account for variation in survival observed among individual samples.

In the cases where control survival data was not available, extended survival was used as the best estimate of impingement survival. Standard errors for initial and extended survival were calculated using binomial procedures (Snedecor and Cochran 1967):

$$S.E. = \left(\frac{P_e \; (1-P_e)}{N_e} \right)^{1/2}$$

Effects of conductivity and water temperature on white perch and striped bass survival were examined. Mean conductivity and mean water temperature were calculated for individual collections by averaging measurements made in the holding facility duringthe extended survival observation period.

It was observed that the 108-hour white perch survival was consistently below 30 percent at water temperatures less than 3.5 C except when conductivity exceeded 2000 μmho/cm. Graphical analysis of survival data indicated a probable relationship with water temperatures up to 4.5 C, therefore survival data were grouped into categories either greater than or less than 4.5 C. The relationship of survival at 108 hours to conductivity and temperature was examined using linear regression analysis. Conductivity and percent survival were transformed using log (conductivity + 1) and arcsine (square root percentage survival) to improve the linear fit and normalize the percentage survival data. Samples with less than ten fish were excluded from the data set to reduce variability introduced by small sample sizes.

4.2 RESULTS

4.2.1 Initial And Extended Survival Of Impinged Fish

A total of 26 species representing 14 families were collected in sufficient numbers ($n \geq 10$) for discussion (Table 4-1, Table 4-2). Species which did not total at least 10 fish were combined within family for survival estimates. The largest number of fish were collected from the family Percichthyidae, followed by the Osmeridae, Clupeidae, and Soleidae.

4.2.1.1 Percichthyidae

White perch and striped bass were pooled into temporal groups consistent with changes in the treatment of control fish and with the relocation of the screenwash discharge pipe (1975 to mid 1978, mid 1978 to mid 1980, and mid 1980 through 1981). Initial survival for both species was high in all years, exceeding 90 percent in 12 of 15 cases (Table 4-1). Extended survival (96 to 108 hours following collection) was always higher for young-of-the-year (YOY) (50 to 72 percent) fish than for the other life stages collected. Survival from mid 1978 through 1981 was higher than the 1975 to mid 1978 time period for eight of nine species/lifestage categories (Table 4-1).

4.2.1.2 Clupeidae

Data were grouped based on the change in sampling technique that occurred in 1980 (Table 4-1). Control tests were not conducted at various time intervals during 1975-1978 as was done for white perch and striped bass, therefore, a separate survival estimate for this time period was not calculated. Blueback herring young-of-the-year predominated in the collections. Initial survival of Clupeids was lower than that of the Percichtyidaes, and generally was between 70 percent and 90 percent. Extended survival was very low (0 to 3 percent) for the 1975 to mid 1980 collection period. For the 1980 to 1981 time period there was in an increase in extended survival from approximately 1-3 percent to 9-11 percent. All remaining family data sets are combined, without division, into time periods due to the low and variable numbers collected. the three most abundant families were grouped by life stage for discussion. The remaining taxa which were very low in abundance (less than 100 individuals) have been summarized by family without further analysis.

4.2.1.3 Osmeridae

The numbers of rainbow smelt collected varied widely over the years. Initial survival for all life stages exceeded 85 percent. While extended survival was low (2 to 17 percent), there was an increase in survival as the age of fish increased.

4.2.1.4 Soleidae

Both initial and extended survival of all hogchoker life stages exceeded 90 percent (Table 4-2).

4.2.1.5 Gadidae

The initial survival of Atlantic tomcod was above 85 percent with young-of-the-year exhibiting the lowest survival (Table 4-2). Young-of-the-year extended survival was much lower (58 percent) than that of the other two life stages (88 percent).

4.2.1.6 Other Families

With the exception of the bay anchovy (65 percent) and bluefish (20 percent), initial survival of other families generally exceeded 85 percent. Percidae, Cyprinidae, and Gasterosteidae extended survival was high, exceeding 88 percent.

American eel, bay anchovy, bluefish, and drum extended survival was less than 20 percent. Intermediate extended survival was exhibited by northern pipefish and sunfishes.

4.2.2 Initial And Extended Control Survival

Control fish were collected for the most abundant families (Percichthyidae, Clupeidae, Gadidae and Centrarchidae) to evaluate handling effects. Initial survival for all families exceeded 98 percent (Table 4-1, Table 4-2). Extended

TABLE 4-1 SURVIVAL OF PERCICHTHYIDAE AND CLUPEIDAE IMPINGED AT THE BOWLINE POINT PLANT

			Impinged Fish				Control Fish				Adjusted Survival	
Taxa	Time Period	Life Stage	Number of Samples	Number of Fish	Initial (%±S.E.)	Extended (%±S.E.)	Number of Samples	Number of Fish	Initial (%±S.E.)	Extended (%±S.E.)	Initial (%±S.E.)	Extended (%±S.E.)
Percichthyidae												
White perch	1975-1978(a)	YOY	45	2,764	97±0.3	54±0.9	27	529	98	54	99	97
		Y	86	3,196	89±0.6	31±0.8	47	706	100	46	89	68
		A	78	499	89±1.4	33±2.1	49	624	100	76	89	43
	1978-1980	YOY	9	271	93±1.5	63±2.9	8	288	100±0	95±1.3	93±1.5	67±3.2
		Y	13	747	93±0.9	51±1.8	15	501	100±0	95±1.0	93±0.9	54±2.0
		A	14	36	92±4.6	50±8.3	14	83	100±0	99±1.2	92±4.6	54±8.5
	1980-1981	YOY	10	238	91±1.9	72±2.9	22	649	100±0	95±0.8	91±1.9	76±3.1
		Y	16	2,003	92±0.6	53±1.1	39	1,385	100±0	100±0	93±0.6	56±1.2
		A	13	47	94±3.6	68±6.8	22	55	100±0	100±0	94±3.6	68±6.8
Striped bass	1975-1978(a)	YOY	32	208	99±0.7	54±3.5	31	100	11	99		
		Y	64	843	91±1.0	25±1.5	73	100	41	91	58	
		A	8	11	91±8.7	27±13.4	--	--	--	--	--(b)	--(b)
	1978-1980	Y	6	14	93±6.9	36±12.8	2	14	100±0	43±13.2	93±6.9	83±39.4
	1980-1981	YOY	5	10	80±12.6	50±15.8	9	92	100±0	99±1.0	80±12.6	51±16.0
		Y	7	648	91±1.1	42±1.9	13	349	99±0.4	89±1.7	92±1.2	47±2.4
Clupeidae												
Alewife	1975-1980	YOY	14	33	73±7.8	3±3.0	5	13	100±0	46±13.8	73±7.8	6.5±6.7
		Y	7	20	85±8.0	0	--	--	--	--	--(b)	--(b)
	1980-1981	YOY	4	32	72±7.9	9±5.2	--	--	--	--	--(b)	--(b)
Blueback herring	1975-1980	YOY	23	158	71±3.1	0	11	289	98±0.7	61±2.9	73±3.7	0
	1980-1981	YOY	10	244	77±2.7	11±2.0	7	379	99±0.4	79±2.1	77±2.7	14±2.6
Combined	1975-1980	YOY	28	219	75±2.9	2±0.9	14	517	99±0.5	70±2.0	76±3.0	3±1.3
		Y	11	63	94±3.1	2±1.6	4	43	100±0	95±3.2	94±3.1	2±1.7
		A	10	65	89±3.8	1±1.5	--	--	--	--	--	--
	1980-1981	YOY	10	296	75±2.5	11±1.8	8	400	99±0.6	78±2.1	76±2.6	14±2.4

(a) As a result of the analytical methodology used to estimate control survival, no standard error could be calculated for control or adjusted survival.

(b) No control tests were conducted; therefore, survival of impinged fish cannot be adjusted for handling effects.

TABLE 4-2 SURVIVAL OF OTHER FISH SPECIES IMPINGED AT THE BOWLINE POINT PLANT (1975-1981)

		Impinged Fish				Control Fish				Adjusted Survival	
Taxa	Life Stage	Number of Samples	Number of Fish	Initial (%±S.E.)	Extended (%±S.E.)	Number of Samples	Number of Fish	Initial (%±S.E.)	Extended (%±S.E.)	Initial (%±S.E.)	Extended (%±S.E.)
Osmeridae											
Rainbow smelt	YOY	6	42	90±4.5	2±2.4						
	Y	20	695	95±0.8	11±1.2						
	A	8	35	86±5.9	17±6.4						
Soleidae											
Hogchoker	YOY	13	227	99±0.8	92±1.8						
	Y	11	189	98±1.0	90±2.2						
Gadidae											
Atlantic tomcod	YOY	8	63	86±4.4	59±6.2	2	11	100±0	100±0	86	59
	Y	--	--	--	--	2	118	100±0	100±0		
	A	39	114	97±1.5	88±3.1	--	--	--	--	--(a)	--(a)
Sciaenidae											
Weakfish, spot	YOY,Y	13	95	88±3.3	18±3.9						
Engraulidae											
Bay anchovy	YOY,Y,A	13	62	64±6.1	5±2.7						
Centrarchidae											
Pumpkinseed, Bluegill, Redbreast, Largemouth bass	YOY,Y,A	22	52	94±3.2	65±6.6	8	19	100±0	100±0	94	65
Cyprinodontidae											
Banded killifish	YOY,Y,A	15	13	100±0	100±0						
Mummichog	YOY,Y,A	10	24	96±4.1	92±5.6						
Gasterosteidae											
Three- and Fourspine stickleback	Y,A	13	33	94±4.2	88±5.7						
Percidae											
Yellow perch, Tessellated darter	YOY,Y,A	12	23	100±0	96±4.2						
Anguillidae											
American eel	A	12	21	90±6.5	5±4.7						
Pomatomidae											
Bluefish	YOY	5	20	70±10.2	5±4.9						
Syngnathidae											
Northern pipefish	YOY,Y,A	10	15	87±8.8	60±12.6						

(a) No control tests were conducted; therefore, survival of impinged fish cannot be adjusted for handling effects.

survival of Centrarchidae and Gadidae was 100 percent (Table 4-2). Percichtyidae and Clupeidae control extended survival ranged from 11.1 to 100 percent and from 46.1 to 95.4 percent, respectively.

4.3.3 Effect Of Temperature And Conductivity On Extended Survival

The relationship between extended survival, water temperature, and conductivity was examined for white perch and striped bass, to investigate apparent seasonal variation in survival. Linear regression analysis demonstrated a correlation between white perch survival at 108 hours and conductivity and water temperature during collection and holding.

When water temperature was less than 4.5 C, water temperature accounted for 32.0 percent of the variation in white perch survival (Table 4-3). Conductivity accounted for 67.9 percent of the variation when water temperatures were above 4.5 C. The two regressions were significant ($\alpha = 0.0001$). Regressions of survival and temperature (>4.5 C) and conductivity (for T $\leq$4.5 C) were not significant.

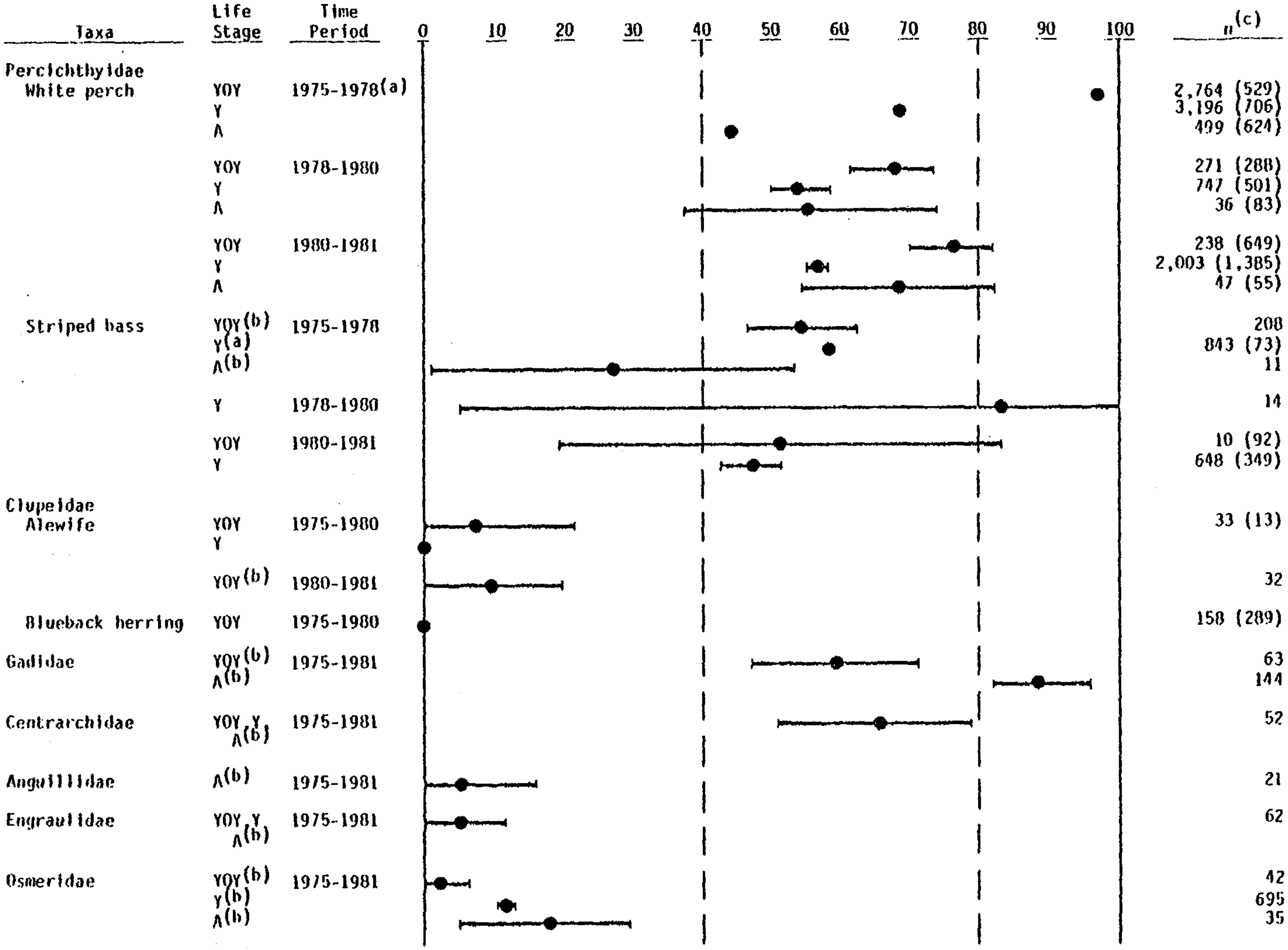
Conductivity and water temperature exert a similar influence on striped bass survival (Table 4-4). Although the data base was smaller, conductivity accounted for 59.5 percent of the variance above 4.5 C and water temperature accounted for 37.6 percent of the variance below 4.5 C.

4.3 DISCUSSION

4.3.1 Survival Of Impinged Fish Adjusted By Control Survival

Initial survival for fishes impinged on continuously rotating screens exceeded 85 percent in the majority of cases. However, based on extended survival it is apparent that different taxa exhibit varing degrees of sensitivity to the stress of impingement. For groups where control survival data was collected, adjustments were made for handling and holding effects (Table 4-1). When control survival data was not available, the extended survival observation was used as the best estimate of impinged fish survival. This method may underestimate the actual ability of the organism to survive impingement since they also include the effects of collection and handling.

The families were grouped according to their ability to survive impingement (Figure 4-1). The data show that with continuously rotating conventional traveling screens, some families show high potential for surviving the impingement process. However, other families, such as the herrings and anchovies, show a low potential for surviving. For this power plant, where white perch and striped bass are major contributors to the impinged population, substantial portions of this population may be rturned unharmed by operating the screens continuously during peak periods of impingement. However, in situations where the more sensitive species make the greatest contribution to the impinged population, more advanced intake screening techniques may be required to mitigate losses.



(a) Could not calculate 95 percent confidence interval.
(b) Estimate based on extended survival estimate not adjusted by control survival.
(c) n = number of impinged fish in sample (number of control fish).

Figure 4-1 Estimated survival of impinged fish at the Bowline Point Generating Station.

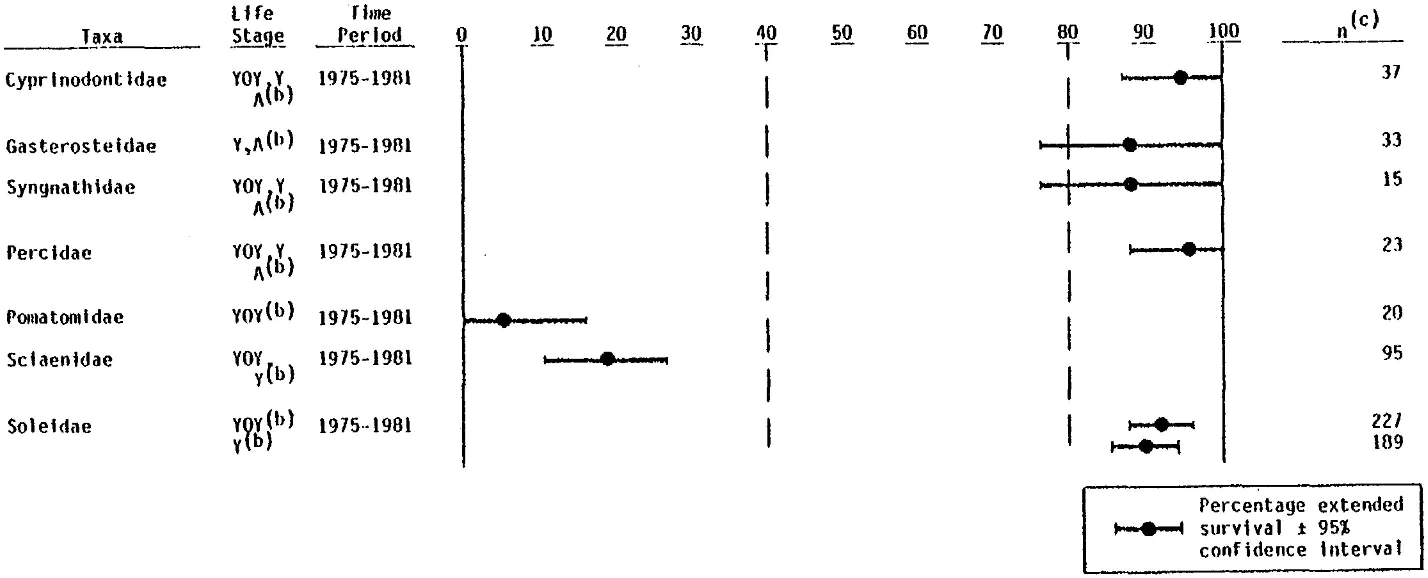


Figure 4-1 Continued.

TABLE 4-3 SUMMARY OF LINEAR REGRESSION ANALYSIS FOR RELATIONSHIP BETWEEN WHITE PERCH EXTENDED SURVIVAL, CONDUCTIVITY, AND TEMPERATURE (T)

I. Arcsine (108 hour survival)$^{\frac{1}{2}}$ vs log (conductivity + 1) with T $\geq$4.5 C.

Source	df	SS	MS	F	Prob > F	r^2
Conductivity	1	3.62712003	3.62712003	67.76	0.0001	0.68
Error	32	1.71282241	0.05352570			
Total	33	5.33994243				

		Standard Error of Estimate
Intercept:	-0.79746805	0.18848672
Slope:	0.23898581	0.02903169

II. Arcsine (108 hour survival)$^{\frac{1}{2}}$ vs T $\leq$4.5 C.

Source	df	SS	MS	F	Prob > F	r^2
Temperature	1	2.65681779	2.65681779	37.70	0.0001	0.32
Error	80	5.63832934	0.07047912			
Total	81	8.29514712				

		Standard Error of Estimate
Intercept:	0.34460529	0.05913335
Slope:	0.13366957	0.02177118

TABLE 4-4 SUMMARY OF LINEAR REGRESSION ANALYSIS FOR RELATIONSHIP BETWEEN STRIPED BASS EXTENDED SURVIVAL, CONDUCTIVITY, AND TEMPERATURE (T)

I. Arcsine (108 hour survival)$^{1/2}$ vs log (conductivity + 1) with $T \geq 4.5$ C.

Source	df	SS	MS	F	Prob > F	r^2
Conductivity	1	0.47823665	0.47823665	7.34	0.0423	0.59
Error	5	0.32577493	0.06515499			
Total	6					

		Standard Error of Estimate
Intercept:	0.24617539	0.14938861
Slope:	0.00020314	0.00007498

II. Arcsine (108 hour survival)$^{1/2}$ vs $T \leq 4.5$ C.

Source	df	SS	MS	F	Prob > F	r^2
Temperature	1	1.83103209	1.83103209	18.11	0.0002	0.38
Error	30	3.03388219	0.10112941			
Total	31	4.86491428				

		Standard Error of Estimate
Intercept:	0.15752713	0.12514070
Slope:	0.21046046	0.04946082

4.3.2 Effect Of Temperature And Conductivity

Seasonal impingement survival information is also important in evaluating the effectiveness of a given mode of screen operation at reducing impingement mortality. Increased mortality due to the addition of stress at low temperatures has been noted in other studies (Stanley and Colby 1971; Colby 1973; Umminger and Gist 1973; and Otto et al. 1976). Such mortality may be attributed to osmoregulatory dysfunction (Stanley and Colby 1971; Colby 1973). Also, temporary freezing of fish out of water during screen rotation before they reach the spray wash may be a source of additional stress.

An improvement in extended survival observed with increased conductivity is similar to the prophylactic effect of salt reported by Collins and Hulsey (1963), Miles et al. (1974) and Hattingh et al. (1975). Such enhanced survival in the holding facility may be related to the alleviation of osmoregulatory dysfunction or hyperglycemia (Wedemeyer 1972; Miles et al. 1974; and Hattingh and Van Pletzer 1974) associated with stress.

REFERENCES

Christensen, S.W., W. Van Winkle, L.W. Barnthouse, and D.S. Vaughan. 1981. Science and the Law: Confluence and conflict on the Hudson River. Environmental Impact Assess. Rev. 2(1):63-88.

Colby, P.J. 1973. Response of the alewives, Alosa pseudoharengus, to environmental change, in Responses of Fish to Environmental Changes (W. Chavin, ed.), pp. 163-198. C. C. Thomas, Springfield, Ill.

Collins, J.L., and A.H. Hulsey. 1963. Hauling mortality of threadfin shad reduced with M.S. 222 and salt. Prog. Fish-Cult. 25:105-106.

DeAngelis, D.L., S.W. Christensen, and A.G. Clark. 1977. Responses of a fish population to young-of-the-year mortality. J. Fish. Res. Board Can. 34(11):2124-2132.

Ecological Analysts, Inc. 1981a. Bowline Point Generating Station Entrainment Abundance and Survival Studies. 1979 Annual Report with Overview of 1975-1979 Studies. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1981b. Bowline Point Generating Station Entrainment Abundance Studies. 1980 Annual Report. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. (EA). 1979. Bowline Point Generating Station Impingement Survival Studies: 1975-1978 Overview Report. Prepared for Orange and Rockland Utilities, Inc.

Fleiss, J.L. 1973. Statistical Methods for Rates and Proportions, pp. 92-96. Wiley, N.Y.

Grimes, C.B. 1975. Entrapment of fishes on intake water screens at a steam electric generating station. Ches. Sci. 16(3):172-177.

Hanson, C.H., J.R. White, and H.W. Li. 1977. Entrapment and impingement of fishes by power plant cooling water intakes: an overview. Marine Fish. Rev. 39(10):7-17.

Hattingh, J., and A.J.J. Van Pletzen. 1974. The influence of capture and transportation on some blood parameters of fresh water fish. Comp. Biochem. Physiol. 49A:607-609.

Hattingh, J., F.L. Fourie, and J.H.J. Van Vuren. 1975. The transport of freshwater fish. J. Fish. Biol. 7:447-449.

Jensen, L.D. (ed.) 1977. Third National Workshop on Entrainment and Impingement. Section 316(b)-Research and Compliance. EA Communications.

Jensen, L.D. (ed.) 1978. Fourth National Workshop on Entrainment and Impingement. EA Communications.

King, L.R., J.B. Hutchison, Jr., and T.G. Huggins. 1978. Impingement survival studies on white perch, striped bass, and Atlantic tomcod at three Hudson River power plants, in Fourth National Workshop on Entrainment and Impingement (L.D. Jensen, ed.). EA Communications, Melville, NY

Mathur, D., P.G. Heisey, and N.C. Magnusson. 1977. Impingement of fishes at Peach Bottom Atomic Power Station, Pennsylvania. Trans. Amer. Fish. Soc. 106(3):258-267.

Miles, H.M., S.M. Loehner, D.T. Michaud, and S.L. Salivar. 1974. Physiological responses of hatchery reared muskellunge (Esox masquinongy) to handling. Trans. Amer. Fish. Soc. 103:336-342.

Otto, R.G., M.A. Kitchel, and J. O'Hara Rice. 1976. Lethal and preferred temperatures of the alewife (Alosa pseudoharengus) in Lake Michigan. Trans. Amer. Fish. Soc 105(1):96-106.

Snedecor, G.W. and W.G. Cochran. 1967. Statistical Methods. Iowa State University Press.

Stanley, J.G., and P.G. Colby. 1971. Effects of temperature on electrolyte balance and osmoregulation in alewife (Alosa pseudoharengus) in fresh and sea water. Trans. Amer. Fish. Soc. 100:624-638.

Umminger, B.L., and D.H. Gist. 1973. Effects of thermal acclimation on physiological responses to handling stress, cortisol and aldosterone injections in the goldfish, Carassius auratus. Comp. Biochem. Physiol. 44A:967-977.

Umminger, B.L. 1971. Osmoregulatory role of serum glucose in freshwater-adapted killifish (fundulus heteroclitus) at temperatures near freezing. Comp. Biochem. Physiol. 38A:141-145.

Van Winkle, W. (ed.). 1971. Assessing the effects of power-plant induced mortality on fish populations. Pergamon, New York. 380 pp.

Van Winkle, W., D.L. DeAngelis, and S.R. Blum. 1978. A density-dependent function for fishing mortality rate and a method for determining elements of a Leslie matrix with density dependent parameters. Trans. Am. Fish. Soc. 107(3):395-401.

Wedemeyer, G. 1972. Some physiological consequences of handling stress in the juvenile coho salmon (Onchorhynchus kitsutch) and steelhead trout (Salmo gairdneri). J. Fish. Res. Board. Can. 29:1780-1783.

APPENDIX A

DAILY DENSITIES OF SELECTED ICHTHYOPLANKTON TAXA COLLECTED DURING THE ENTRAINMENT ABUNDANCE STUDY BOWLINE POINT GENERATING STATION, 1981

LIST OF TABLES

TABLE A-1 DAILY DENSITY OF TOTAL ICHTHYOPLANKTON COLLECTED DURING THE ENTRAINMENT ABUNDANCE STUDY, BOWLINE POINT GENERATING STATION, 1981

				DAILY AVERAGE DENSITY (NO./1000 CU M)					
DATE	AVERAGE TEMPERATURE (DEGREES C)	AVERAGE CONDUCTIVITY (MICROMHOS)	TOTAL VOLUME (CU M)	EGGS	YOLK-SAC LARVAE	LARVAE	JUVENILES	UID	TOTAL (EXCLUDING EGGS)
05/12/81	14.0	3300.	950.3	0.0	0.0	2.1	0.0	1.1	3.2
05/14/81	--	--	954.6	6.3	0.0	4.2	1.0	0.0	5.2
05/17/81	--	--	953.7	44.0	1.0	17.8	0.0	5.2	24.1
05/21/81	17.5	247.	957.7	63.7	2.1	74.1	0.0	7.3	83.5
05/24/81	16.3	247.	964.6	24.9	0.0	113.0	0.0	17.6	130.6
05/28/81	20.4	2500.	964.9	4.1	0.0	37.3	0.0	19.7	57.0
05/31/81	20.6	3000.	943.2	0.0	1.1	126.2	1.1	4.2	132.5
06/04/81	20.9	2600.	974.3	13.3	0.0	178.6	2.1	5.1	185.8
06/07/81	22.0	2200.	967.4	2.1	0.0	358.7	0.0	12.4	371.1
06/26/81	25.6	835.	810.8	2.5	0.0	495.8	9.9	2.5	508.1
06/27/81	26.3	845.	813.9	0.0	0.0	523.4	13.5	0.0	536.9
06/29/81	25.6	793.	815.5	0.0	0.0	663.4	0.0	0.0	663.4
06/30/81	25.9	795.	823.2	1.2	0.0	840.6	7.3	6.1	854.0
07/07/81	28.2	12200.	978.6	0.0	0.0	0.0	0.0	0.0	0.0
07/09/81	27.7	11400.	979.8	0.0	0.0	480.7	2.0	0.0	482.8
07/11/81	27.6	10600.	983.7	0.0	1.0	296.8	3.0	1.0	301.9
07/12/81	28.2	11300.	991.2	0.0	1.0	632.6	5.0	10.1	648.7
07/14/81	26.3	10700.	983.9	15.2	4.1	1176.9	4.1	0.0	1185.1
07/15/81	26.3	11200.	997.7	8.0	0.0	1380.2	6.0	0.0	1386.2
07/16/81	24.1	--	1004.3	6.0	2.0	1191.9	2.0	9.0	1204.8
07/24/81	26.8	12700.	993.5	0.0	0.0	662.3	6.0	0.0	668.3
07/30/81	28.8	13100.	791.2	0.0	0.0	944.1	1.3	0.0	945.4
08/01/81	28.2	12700.	780.6	0.0	0.0	1122.2	9.0	0.0	1131.2
08/02/81	28.2	12600.	784.9	0.0	0.0	823.0	5.1	0.0	828.1
08/14/81	28.1	14800.	954.1	0.0	2.1	1200.1	22.0	6.3	1230.5
08/15/81	28.4	15900.	990.8	0.0	0.0	625.8	40.4	0.0	666.1
08/24/81	25.5	12900.	941.2	0.0	0.0	491.9	12.7	0.0	504.7
08/25/81	25.9	13000.	846.0	0.0	0.0	452.7	2.4	0.0	455.1
08/27/81	26.1	13400.	950.2	0.0	0.0	664.1	3.2	1.1	668.3
09/02/81	23.7	13700.	911.9	0.0	0.0	195.2	16.4	0.0	211.6

NOTE: Dashes (--) indicate data not available because of gear malfunction.

TABLE A-2 DAILY DENSITY OF BAY ANCHOVIES COLLECTED DURING THE ENTRAINMENT ABUNDANCE STUDY, BOWLINE POINT GENERATING STATION, 1981

DATE	AVERAGE TEMPERATURE (DEGREES C)	AVERAGE CONDUCTIVITY (MICROMHOS)	TOTAL VOLUME (CU M)	DAILY AVERAGE DENSITY (NO./1000 CU M)					
				EGGS	YOLK-SAC LARVAE	LARVAE	JUVENILES	UID	TOTAL (EXCLUDING EGGS)
05/12/81	14.0	3300.	950.3	0.0	0.0	0.0	0.0	0.0	0.0
05/14/81	--	--	954.6	0.0	0.0	0.0	0.0	0.0	0.0
05/17/81	--	--	953.7	0.0	0.0	0.0	0.0	0.0	0.0
05/21/81	17.5	247.	957.7	0.0	0.0	0.0	0.0	0.0	0.0
05/24/81	16.3	247.	964.6	0.0	0.0	0.0	0.0	0.0	0.0
05/28/81	20.4	2500.	964.9	0.0	0.0	0.0	0.0	0.0	0.0
05/31/81	20.6	3000.	943.2	0.0	0.0	1.1	0.0	0.0	1.1
06/04/81	20.9	2600.	974.3	0.0	0.0	0.0	0.0	0.0	0.0
06/07/81	22.0	2200.	967.4	0.0	0.0	0.0	0.0	0.0	0.0
06/26/81	25.6	835.	810.8	0.0	0.0	408.2	0.0	0.0	408.2
06/27/81	26.3	845.	813.9	0.0	0.0	474.3	0.0	0.0	474.3
06/29/81	25.6	793.	815.5	0.0	0.0	529.7	0.0	0.0	529.7
06/30/81	25.9	795.	823.2	0.0	0.0	818.8	0.0	0.0	818.8
07/07/81	28.2	12200.	978.6	0.0	0.0	0.0	0.0	0.0	0.0
07/09/81	27.7	11400.	979.8	0.0	0.0	475.6	0.0	0.0	475.6
07/11/81	27.6	10600.	983.7	0.0	0.0	249.1	0.0	0.0	249.1
07/12/81	28.2	11300.	991.2	0.0	0.0	624.5	0.0	0.0	624.5
07/14/81	26.3	10700.	983.9	15.2	0.0	1086.5	1.0	0.0	1087.5
07/15/81	26.3	11200.	997.7	8.0	0.0	1371.2	0.0	0.0	1371.2
07/16/81	24.1	--	1004.3	6.0	0.0	1163.0	0.0	0.0	1163.0
07/24/81	26.8	12700.	993.5	0.0	0.0	662.3	5.0	0.0	667.3
07/30/81	28.8	13100.	791.2	0.0	0.0	942.9	0.0	0.0	942.9
08/01/81	28.2	12700.	780.6	0.0	0.0	1119.7	9.0	0.0	1128.6
08/02/81	28.2	12600.	784.9	0.0	0.0	821.8	5.1	0.0	826.9
08/14/81	28.1	14800.	954.1	0.0	0.0	1191.7	21.0	6.3	1218.9
08/15/81	28.4	15900.	990.8	0.0	0.0	625.8	38.4	0.0	664.1
08/24/81	25.5	12900.	941.2	0.0	0.0	488.7	7.4	0.0	496.2
08/25/81	25.9	13000.	846.0	0.0	0.0	448.0	2.4	0.0	450.4
08/27/81	26.1	13400.	950.2	0.0	0.0	656.7	1.1	0.0	657.8
09/02/81	23.7	13700.	911.9	0.0	0.0	186.4	15.4	0.0	201.8

NOTE: Dashes (--) indicate data not available because of gear malfunction.

TABLE A-3 DAILY DENSITY OF STRIPED BASS COLLECTED DURING THE ENTRAINMENT ABUNDANCE STUDY, BOWLINE POINT GENERATING STATION,1981

				DAILY AVERAGE DENSITY (NO./1000 CU M)					
DATE	AVERAGE TEMPERATURE (DEGREES C)	AVERAGE CONDUCTIVITY (MICROMHOS)	TOTAL VOLUME (CU M)	EGGS	YOLK-SAC LARVAE	LARVAE	JUVENILES	UID	TOTAL (EXCLUDING EGGS)
05/12/81	14.0	3300.	950.3	0.0	0.0	0.0	0.0	0.0	0.0
05/14/81	--	--	954.6	0.0	0.0	0.0	0.0	0.0	0.0
05/17/81	--	--	953.7	0.0	1.0	1.0	0.0	0.0	2.1
05/21/81	17.5	247.	957.7	0.0	2.1	1.0	0.0	0.0	3.1
05/24/81	16.3	247.	964.6	0.0	0.0	15.6	0.0	0.0	15.6
05/28/81	20.4	2500.	964.9	0.0	0.0	0.0	0.0	0.0	0.0
05/31/81	20.6	3000.	943.2	0.0	1.1	91.2	0.0	0.0	92.2
06/04/81	20.9	2600.	974.3	0.0	0.0	105.7	0.0	0.0	105.7
06/07/81	22.0	2200.	967.4	0.0	0.0	207.8	0.0	0.0	207.8
06/26/81	25.6	835.	810.8	0.0	0.0	24.7	8.6	0.0	33.3
06/27/81	26.3	845.	813.9	0.0	0.0	30.7	2.5	0.0	33.2
06/29/81	25.6	793.	815.5	0.0	0.0	2.5	0.0	0.0	2.5
06/30/81	25.9	795.	823.2	0.0	0.0	0.0	3.6	0.0	3.6
07/07/81	28.2	12200.	978.6	0.0	0.0	0.0	0.0	0.0	0.0
07/09/81	27.7	11400.	979.8	0.0	0.0	0.0	0.0	0.0	0.0
07/11/81	27.6	10600.	983.7	0.0	0.0	0.0	0.0	0.0	0.0
07/12/81	28.2	11300.	991.2	0.0	0.0	0.0	0.0	0.0	0.0
07/14/81	26.3	10700.	983.9	0.0	0.0	0.0	0.0	0.0	0.0
07/15/81	26.3	11200.	997.7	0.0	0.0	0.0	0.0	0.0	0.0
07/16/81	24.1	--	1004.3	0.0	0.0	0.0	0.0	0.0	0.0
07/24/81	26.8	12700.	993.5	0.0	0.0	0.0	0.0	0.0	0.0
07/30/81	28.8	13100.	791.2	0.0	0.0	0.0	0.0	0.0	0.0
08/01/81	28.2	12700.	780.6	0.0	0.0	0.0	0.0	0.0	0.0
08/02/81	28.2	12600.	784.9	0.0	0.0	0.0	0.0	0.0	0.0
08/14/81	28.1	14800.	954.1	0.0	0.0	0.0	0.0	0.0	0.0
08/15/81	28.4	15900.	990.8	0.0	0.0	0.0	0.0	0.0	0.0
08/24/81	25.5	12900.	941.2	0.0	0.0	0.0	0.0	0.0	0.0
08/25/81	25.9	13000.	846.0	0.0	0.0	0.0	0.0	0.0	0.0
08/27/81	26.1	13400.	950.2	0.0	0.0	0.0	0.0	0.0	0.0
09/02/81	23.7	13700.	911.9	0.0	0.0	0.0	0.0	0.0	0.0

NOTE: Dashes (--) indicate data not available because of gear malfunction.

TABLE A-4 DAILY DENSITY OF WHITE PERCH COLLECTED DURING THE ENTRAINMENT ABUNDANCE STUDY, BOWLINE POINT GENERATING STATION, 1981

				DAILY AVERAGE DENSITY (NO./1000 CU M)					
DATE	AVERAGE TEMPERATURE (DEGREES C)	AVERAGE CONDUCTIVITY (MICROMHOS)	TOTAL VOLUME (CU M)	EGGS	YOLK-SAC LARVAE	LARVAE	JUVENILES	UID	TOTAL (EXCLUDING EGGS)
05/12/81	14.0	3300.	950.3	0.0	0.0	0.0	0.0	0.0	0.0
05/14/81	--	--	954.6	0.0	0.0	0.0	0.0	0.0	0.0
05/17/81	--	--	953.7	43.0	0.0	9.4	0.0	0.0	9.4
05/21/81	17.5	247.	957.7	63.7	0.0	24.0	0.0	0.0	24.0
05/24/81	16.3	247.	964.6	24.9	0.0	63.2	0.0	0.0	63.2
05/28/81	20.4	2500.	964.9	2.1	0.0	3.1	0.0	0.0	3.1
05/31/81	20.6	3000.	943.2	0.0	0.0	6.4	0.0	0.0	6.4
06/04/81	20.9	2600.	974.3	13.3	0.0	27.7	0.0	0.0	27.7
06/07/81	22.0	2200.	967.4	2.1	0.0	116.8	0.0	0.0	116.8
06/26/81	25.6	835.	810.8	2.5	0.0	7.4	1.2	0.0	8.6
06/27/81	26.3	845.	813.9	0.0	0.0	0.0	8.6	0.0	8.6
06/29/81	25.6	793.	815.5	0.0	0.0	3.7	0.0	0.0	3.7
06/30/81	25.9	795.	823.2	1.2	0.0	3.6	3.6	0.0	7.3
07/07/81	28.2	12200.	978.6	0.0	0.0	0.0	0.0	0.0	0.0
07/09/81	27.7	11400.	979.8	0.0	0.0	0.0	0.0	0.0	0.0
07/11/81	27.6	10600.	983.7	0.0	0.0	0.0	0.0	0.0	0.0
07/12/81	28.2	11300.	991.2	0.0	0.0	0.0	0.0	0.0	0.0
07/14/81	26.3	10700.	983.9	0.0	0.0	0.0	0.0	0.0	0.0
07/15/81	26.3	11200.	997.7	0.0	0.0	0.0	0.0	0.0	0.0
07/16/81	24.1	--	1004.3	0.0	0.0	0.0	0.0	0.0	0.0
07/24/81	26.8	12700.	993.5	0.0	0.0	0.0	0.0	0.0	0.0
07/30/81	28.8	13100.	791.2	0.0	0.0	0.0	0.0	0.0	0.0
08/01/81	28.2	12700.	780.6	0.0	0.0	0.0	0.0	0.0	0.0
08/02/81	28.2	12600.	784.9	0.0	0.0	0.0	0.0	0.0	0.0
08/14/81	28.1	14800.	954.1	0.0	0.0	0.0	0.0	0.0	0.0
08/15/81	28.4	15900.	990.8	0.0	0.0	0.0	0.0	0.0	0.0
08/24/81	25.5	12900.	941.2	0.0	0.0	0.0	0.0	0.0	0.0
08/25/81	25.9	13000.	846.0	0.0	0.0	0.0	0.0	0.0	0.0
08/27/81	26.1	13400.	950.2	0.0	0.0	0.0	0.0	0.0	0.0
09/02/81	23.7	13700.	911.9	0.0	0.0	0.0	0.0	0.0	0.0

NOTE: Dashes (--) indicate data not available because of gear malfunction.

TABLE A-5 DAILY DENSITY OF CLUPEIDS COLLECTED DURING THE ENTRAINMENT ABUNDANCE STUDY, BOWLINE POINT GENERATING STATION,1981

				DAILY AVERAGE DENSITY (NO./1000 CU M)					
DATE	AVERAGE TEMPERATURE (DEGREES C)	AVERAGE CONDUCTIVITY (MICROMHOS)	TOTAL VOLUME (CU M)	EGGS	YOLK-SAC LARVAE	LARVAE	JUVENILES	UID	TOTAL (EXCLUDING EGGS)
05/12/81	14.0	3300.	950.3	0.0	0.0	0.0	0.0	0.0	0.0
05/14/81	--	--	954.6	6.3	0.0	2.1	0.0	0.0	2.1
05/17/81	--	--	953.7	0.0	0.0	4.2	0.0	0.0	4.2
05/21/81	17.5	247.	957.7	0.0	0.0	40.7	0.0	0.0	40.7
05/24/81	16.3	247.	964.6	0.0	0.0	23.8	0.0	0.0	23.8
05/28/81	20.4	2500.	964.9	0.0	0.0	3.1	0.0	0.0	3.1
05/31/81	20.6	3000.	943.2	0.0	0.0	3.2	0.0	0.0	3.2
06/04/81	20.9	2600.	974.3	0.0	0.0	10.3	0.0	0.0	10.3
06/07/81	22.0	2200.	967.4	0.0	0.0	6.2	0.0	0.0	6.2
06/26/81	25.6	835.	810.8	0.0	0.0	0.0	0.0	0.0	0.0
06/27/81	26.3	845.	813.9	0.0	0.0	0.0	0.0	0.0	0.0
06/29/81	25.6	793.	815.5	0.0	0.0	0.0	0.0	0.0	0.0
06/30/81	25.9	795.	823.2	0.0	0.0	0.0	0.0	0.0	0.0
07/07/81	28.2	12200.	978.6	0.0	0.0	0.0	0.0	0.0	0.0
07/09/81	27.7	11400.	979.8	0.0	0.0	0.0	2.0	0.0	2.0
07/11/81	27.6	10600.	983.7	0.0	0.0	0.0	2.0	0.0	2.0
07/12/81	28.2	11300.	991.2	0.0	0.0	0.0	5.0	0.0	5.0
07/14/81	26.3	10700.	983.9	0.0	0.0	0.0	0.0	0.0	0.0
07/15/81	26.3	11200.	997.7	0.0	0.0	0.0	5.0	0.0	5.0
07/16/81	24.1	--	1004.3	0.0	0.0	0.0	2.0	0.0	2.0
07/24/81	26.8	12700.	993.5	0.0	0.0	0.0	1.0	0.0	1.0
07/30/81	28.8	13100.	791.2	0.0	0.0	0.0	0.0	0.0	0.0
08/01/81	28.2	12700.	780.6	0.0	0.0	0.0	0.0	0.0	0.0
08/02/81	28.2	12600.	784.9	0.0	0.0	0.0	0.0	0.0	0.0
08/14/81	28.1	14800.	954.1	0.0	0.0	0.0	1.0	0.0	1.0
08/15/81	28.4	15900.	990.8	0.0	0.0	0.0	1.0	0.0	1.0
08/24/81	25.5	12900.	941.2	0.0	0.0	0.0	0.0	0.0	0.0
08/25/81	25.9	13000.	846.0	0.0	0.0	0.0	0.0	0.0	0.0
08/27/81	26.1	13400.	950.2	0.0	0.0	0.0	0.0	0.0	0.0
09/02/81	23.7	13700.	911.9	0.0	0.0	0.0	0.0	0.0	0.0

NOTE: Dashes (--) indicate data not available because of gear malfunction.

APPENDIX B

LENGTH-FREQUENCY DISTRIBUTIONS OF SELECTED ICHTHYOPLANKTON TAXA COLLECTED DURING THE ENTRAINMENT ABUNDANCE STUDY BOWLINE POINT GENERATING STATION, 1981

LIST OF TABLES

TABLE B-1 LENGTH-FREQUENCY OF BAY ANCHOVIES COLLECTED DURING THE ENTRAINMENT ABUNDANCE STUDY, BOWLINE POINT GENERATING STATION, 1981

					LENGTH INTERVALS (MM)										RANGE		
DATE	P	N	X	SD	0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0 28.9	29.0 999.9	MIN	MED	MAX
12 MAY 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
17 MAY 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
24 MAY 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
31 MAY 81	1	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 JUN 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
26 JUN 81	672	45	15.7	3.5	0	1	1	3	11	15	13	1	0	0	4.2	15.9	21.5
29 JUN 81	1056	50	15.6	4.5	0	0	7	2	11	11	14	3	2	0	6.7	16.1	25.0
7 JUL 81	661	50	19.7	5.2	0	1	2	3	1	6	11	16	10	0	5.7	21.0	28.0
12 JUL 81	4124	101	19.7	5.5	0	5	1	5	5	9	23	31	21	1	4.1	21.0	29.0
24 JUL 81	634	29	20.0	7.3	0	0	5	1	1	1	2	12	5	2	6.5	22.4	32.5
30 JUL 81	1572	55	16.5	5.4	0	0	5	8	10	8	12	5	7	0	6.8	16.5	27.6
2 AUG 81	623	26	14.8	7.0	0	0	4	8	5	1	3	3	1	1	7.2	12.2	37.9
14 AUG 81	1779	36	19.5	7.8	0	1	0	9	4	1	4	3	10	4	5.2	20.0	33.7
24 AUG 81	1392	81	15.5	5.2	0	0	1	27	17	11	9	10	5	1	6.2	14.0	30.2
2 SEP 81	146	38	20.6	8.3	0	0	1	5	6	4	6	3	4	9	8.2	19.8	38.5
SUMMARY TOTALS	12660	511	17.8	6.2	0	8	27	71	71	67	97	87	65	18	4.1		38.5

NOTE: P=NUMBER OF UNMEASURED ORGANISMS; N=NUMBER OF LENGTHS; MIN=SHORTEST LENGTH; X=MEAN LENGTH; MED=MEDIAN LENGTH; SD=STANDARD DEVIATION; MAX=GREATEST LENGTH; NA=DATA NOT AVAILABLE.

TABLE B-2 LENGTH-FREQUENCY OF STRIPED BASS COLLECTED DURING THE ENTRAINMENT ABUNDANCE STUDY, BOWLINE POINT GENERATING STATION, 1981

DATE	P	N	X	SD	LENGTH INTERVALS (MM) 0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0 28.9	29.0 999.9	RANGE MIN	MED	MAX
12 MAY 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
17 MAY 81	0	5	6.3	0.5	0	1	4	0	0	0	0	0	0	0	5.5	6.4	6.8
24 MAY 81	1	14	6.9	1.1	0	2	12	0	0	0	0	0	0	0	5.4	6.7	8.4
31 MAY 81	139	51	7.9	1.5	0	3	35	13	0	0	0	0	0	0	5.5	7.8	10.8
7 JUN 81	176	25	8.9	2.0	0	2	9	12	2	0	0	0	0	0	5.6	9.2	12.8
26 JUN 81	3	51	13.3	3.2	0	1	1	12	29	6	0	1	0	1	5.4	12.9	29.4
29 JUN 81	0	5	15.4	2.1	0	0	0	0	2	2	1	0	0	0	13.5	15.0	19.0
7 JUL 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
12 JUL 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
24 JUL 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 JUL 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
2 AUG 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
14 AUG 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
24 AUG 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
2 SEP 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
SUMMARY TOTALS	319	151	10.0	3.6	0	9	61	37	33	8	1	1	0	1	5.4		29.4

NOTE: P=NUMBER OF UNMEASURED ORGANISMS; N=NUMBER OF LENGTHS; MIN=SHORTEST LENGTH; X=MEAN LENGTH; MED=MEDIAN LENGTH SD=STANDARD DEVIATION; MAX=GREATEST LENGTH; NA=DATA NOT AVAILABLE.

TABLE B-3 LENGTH-FREQUENCY OF WHITE PERCH COLLECTED DURING THE ENTRAINMENT ABUNDANCE STUDY, BOWLINE POINT GENERATING STATION,1981

DATE	P	N	X	SD	LENGTH INTERVALS (MM) 0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0 28.9	29.0 999.9	RANGE MIN	MED	MAX
12 MAY 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
17 MAY 81	0	32	4.4	0.6	0	31	1	0	0	0	0	0	0	0	3.7	4.3	6.3
24 MAY 81	36	28	4.9	0.8	0	25	3	0	0	0	0	0	0	0	3.5	4.8	6.9
31 MAY 81	2	31	5.9	1.9	0	19	9	3	0	0	0	0	0	0	3.1	5.8	9.9
7 JUN 81	88	25	8.3	2.7	0	9	3	12	1	0	0	0	0	0	3.4	9.8	12.1
26 JUN 81	0	14	12.3	2.6	0	1	0	2	9	2	0	0	0	0	4.7	12.5	16.4
29 JUN 81	0	9	11.9	2.1	0	0	1	3	5	0	0	0	0	0	7.0	12.5	13.8
7 JUL 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
12 JUL 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
24 JUL 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 JUL 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
2 AUG 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
14 AUG 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
24 AUG 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
2 SEP 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
SUMMARY TOTALS	126	139	6.8	3.2	0	85	17	20	15	2	0	0	0	0	3.1		16.4

NOTE: P=NUMBER OF UNMEASURED ORGANISMS; N=NUMBER OF LENGTHS; MIN=SHORTEST LENGTH; X=MEAN LENGTH; MED=MEDIAN LENGTH; SD=STANDARD DEVIATION; MAX=GREATEST LENGTH; NA=DATA NOT AVAILABLE.

TABLE B-4 LENGTH-FREQUENCY OF CLUPEIDS COLLECTED DURING THE ENTRAINMENT ABUNDANCE STUDY, BOWLINE POINT GENERATING STATION,1981

					LENGTH INTERVALS (MM)										RANGE		
DATE	P	N	X	SD	0.0 2.9	3.0 5.9	6.0 8.9	9.0 11.9	12.0 14.9	15.0 17.9	18.0 20.9	21.0 23.9	24.0 28.9	29.0 999.9	MIN	MED	MAX
12 MAY 81	1	1	5.0	0.0	0	1	0	0	0	0	0	0	0	0	5.0	5.0	5.0
17 MAY 81	38	5	6.8	1.7	0	2	2	1	0	0	0	0	0	0	5.3	6.5	9.5
24 MAY 81	20	6	10.4	3.0	0	0	3	2	0	1	0	0	0	0	8.3	9.1	16.2
31 MAY 81	4	9	9.0	1.3	0	0	5	4	0	0	0	0	0	0	7.6	8.4	11.8
7 JUN 81	0	6	11.1	3.9	0	0	2	1	2	1	0	0	0	0	6.0	11.4	17.0
26 JUN 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
29 JUN 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 JUL 81	1	3	46.0	4.6	0	0	0	0	0	0	0	0	0	3	41.0	47.0	50.0
12 JUL 81	1	11	46.1	3.3	0	0	0	0	0	0	0	0	0	11	42.0	45.0	51.5
24 JUL 81	0	1	25.7	0.0	0	0	0	0	0	0	0	0	1	0	25.7	25.7	25.7
30 JUL 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
2 AUG 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
14 AUG 81	0	2	51.5	6.4	0	0	0	0	0	0	0	0	0	2	47.0	51.5	56.0
24 AUG 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
2 SEP 81	0	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
SUMMARY TOTALS	65	44	23.2	18.5	0	3	12	8	2	2	0	0	1	16	5.0		56.0

NOTE: P=NUMBER OF UNMEASURED ORGANISMS; N=NUMBER OF LENGTHS; MIN=SHORTEST LENGTH; X=MEAN LENGTH; MED=MEDIAN LENGTH; SD=STANDARD DEVIATION; MAX=GREATEST LENGTH; NA=DATA NOT AVAILABLE.

APPENDIX C

DATA USED FOR EVALUATING EFFECTS OF SCHEDULED PLANT OUTAGE AT BOWLINE 1981

LIST OF TABLES

LIST OF TABLES (CONT.)

TABLE C-1 WEEKLY COOLING WATER FLOW AT BOWLINE 10 MAY - 5 SEPTEMBER 1981

	Flow in Million Cubic Meters			
	Actual			
Week	Unit 1	Unit 2	Total	Projected Total
5/10-16	9.8	0.0	9.8	19.6
5/17-23	9.9	0.0	9.9	19.7
5/24-30	9.6	4.3	14.0	19.6
5/31-6/6	7.8	5.7	13.5	19.7
6/7-13	9.8	0.0	9.8	19.6
6/14-20	7.4	8.6	16.0	22.8
6/21-27	0.0	11.9	11.9	23.7
6/28-7/4	1.7	9.8	11.5	23.1
7/5-11	12.1	8.5	20.5	24.1
7/12-18	12.1	12.1	24.1	24.1
7/19-25	12.1	12.1	24.1	24.1
7/26-8/1	5.2	12.1	17.2	24.1
8/2-8	1.7	11.7	13.4	23.9
8/9-15	12.1	8.4	20.5	24.1
8/16-22	11.3	1.7	13.0	22.6
8/23-29	12.1	0.0	12.1	24.1
8/30-9/5	6.9	9.6	16.5	24.1
Total	141.3	116.4	257.8	383.3

TABLE C-2 WEEKLY MEAN DENSITIES FOR STRIPED BASS COLLECTED DURING ENTRAINMENT SAMPLING AT BOWLINE 1981

Week	Density Per 1,000m^3			
	Egg	Yolk-Sac Larvae	Post Yolk-Sac Larvae	Juvenile
5/10-16	0	0	0	0
5/17-23	0	1.6	1.0	0
5/24-30	0	0	7.8	0
5/31-6/6	0	0.6	98.5	0
6/7-13	0	0	207.8	0
6/14-20*	0	0	75.9	2.4
6/21-27	0	0	27.7	5.6
6/28-7/4	0	0	1.3	1.8
7/5-11	0	0	0	0
7/12-18	0	0	0	0
7/19-25	0	0	0	0
7/26-8/1	0	0	0	0
8/2-8	0	0	0	0
8/9-15	0	0	0	0
8/16-22*	0	0	0	0
8/23-29	0	0	0	0
8/30-9/5	0	0	0	0

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* No sampling. Estimate geometric mean of two adjacent weeks.

TABLE C-3 WEEKLY MEAN DENSITIES FOR WHITE PERCH COLLECTED DURING ENTRAINMENT SAMPLING AT BOWLINE 1981

	Density Per 1,000m^3			
Week	Egg	Yolk-Sac Larvae	Post Yolk-Sac Larvae	Juvenile
5/10-16	0	0	0	0
5/17-23	53.4	0	16.7	0
5/24-30	13.5	0	33.2	0
5/31-6/6	6.7	0	13.9	0
6/7-13	2.1	0	0	0
6/14-20*	1.7	0	1.9	2.2
6/21-27	1.3	0	3.7	4.9
6/28-7/4	0.6	0	3.7	1.8
7/5-11	0	0	0	0
7/12-18	0	0	0	0
7/19-25	0	0	0	0
7/26-8/1	0	0	0	0
8/2-8	0	0	0	0
8/9-15	0	0	0	0
8/16-22*	0	0	0	0
8/23-29	0	0	0	0
8/30-9/5	0	0	0	0

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* No sampling. Estimate geometric mean of two adjacent weeks.

TABLE C-4 WEEKLY MEAN DENSITIES FOR CLUPEIDS COLLECTED DURING ENTRAINMENT SAMPLING AT BOWLINE 1981

	Density Per 1,000m^3			
Week	Egg	Yolk-Sac Larvae	Post Yolk-Sac Larvae	Juvenile
5/10-16	3.2	0	1.0	0
5/17-23	0	0	22.4	0
5/24-30	0	0	13.0	0
5/31-6/6	0	0	6.8	0
6/7-13	0	0	6.2	0
6/14-20*	0	0	2.5	0
6/21-27	0	0	0	0
6/28-7/4	0	0	0	0
7/5-11	0	0	0	1.3
7/12-18	0	0	0	3.0
7/19-25	0	0	0	0
7/26-8/1	0	0	0	0
8/2-8	0	0	0	0
8/9-15	0	0	0	1.0
8/16-22*	0	0	0	0
8/23-29	0	0	0	0
8/30-9/5	0	0	0	0

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* No sampling. Estimate geometric mean of two adjacent weeks.

TABLE C-5 WEEKLY MEAN DENSITIES FOR BAY ANCHOVY COLLECTED DURING ENTRAINMENT SAMPLING AT BOWLINE 1981

Week	Density Per 1,000m^3			
	Egg	Yolk-Sac Larvae	Post Yolk-Sac Larvae	Juvenile
5/10-16	0	0	0	0
5/17-23	0	0	0	0
5/24-30	0	0	0	0
5/31-6/6	0	0	0.6	0
6/7-13	0	0	0	0
6/14-20*	0	0	21.0	0
6/21-27	0	0	441.2	0
6/28-7/4	0	0	674.3	0
7/5-11	0	0	241.6	0
7/12-18	7.3	0	1061.3	0.3
7/19-25	0	0	662.3	5.0
7/26-8/1	0	0	1031.3	4.5
8/2-8	0	0	821.8	5.1
8/9-15	0	0	908.7	29.6
8/16-22*	0	0	694.7	10.5
8/23-29	0	0	531.1	3.7
8/30-9/5	0	0	186.5	15.4

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* No sampling. Estimate geometric mean of two adjacent weeks.

TABLE C-6 ESTIMATES OF MECHANICAL MORTALITY USED FOR CALCULATING THE NUMBER OF INDIVIDUALS CROPPED BY ENTRAINMENT AT BOWLINE, 1981

Species	Life Stage	Mechanical Mortality
Striped bass	Egg	.110
	Yolk-sac larvae	.117
	Post yolk-sac larvae	.106
	Early juveniles	.154
White perch	Egg	.110
	Yolk-sac larvae	.510
	Post yolk-sac larvae	.243
	Early juveniles	.243

TABLE C-7 EQUATIONS AND RESTRICTIONS EMPLOYED TO PREDICT MORTALITY FROM THERMAL STRESS[a]

Striped Bass Yolk-Sac Larvae[b]

REST1 - (516.2 + 11.46 (DISTEM))/55.26
IF (AMBTEM < REST1), THEN AMBTEM = REST1
IF (AMBTEM > 20.0), THEN AMBTEM = 20.0
THERMO = - 559.5 - 259.0(DISTEM) + 1.666 (DISTEM)^{2} + 11.46 (DISTEM)(AMBTEM) + 64.33 (TRANST)^{2} + 516.2 (AMBTEM) - 27.63 (AMBTEM)^{2}

REST2 = (259.0 - 11.46 (AMBTEM))/3.333
IF (DISTEM $\leq$ REST2), THEN THERMO = 0.0

White Perch Yolk-Sac Larvae[b]

THERMO = 99.15 - 7.205 (DISTEM)(TRANST) + 1.451 (DISTEM)(AMBTEM) + 329.3 (TRANST) - 59.21 (AMBTEM)

Striped Bass and White Perch Post Yolk-Sac Larvae and Juveniles

IF (LENGTH > 26), THEN LENGTH = 26.0 mm

THERMO = 22.01 + 1.601 (DISTEM)(AMBTEM) + 3.692 (TRANST)(LENGTH) - 47.92 (AMBTEM) - 0.8174 (AMBTEM)(LENGTH) + 0.2773 (LENGTH)^{2}

Striped Bass and White Perch Eggs

IF (DISTEM < 33), THEN THERMO = 0.0
IF (DISTEM $\geq$ 33), THEN THERMO = 1.00

where

REST1, REST2 = restrictions one and two, respectively
THERMO = percent mortality from thermal stress
DISTEM = discharge (exposure) temperature (C)
AMBTEM = ambient (acclimation) temperature (C)
TRANST = logarithm to the base 10 of transit time (exposure time) in minutes
LENGTH = organism length (mm).

(a) When the calculated percent thermal mortality is less than zero or greater than 100, mortalities of zero and 100 percent are assigned, respectively.

(b) Thermal mortality should not be calculated when ambient temperatures are greater than or equal to 22.0 C. No *Morone* yolk-sac larvae are expected to occur.

TABLE C-8 WEEKLY MEDIAN LENGTHS FOR STRIPED BASS AND WHITE PERCH POST YOLK-SAC LARVAE AND JUVENILES COLLECTED DURING ENTRAINMENT SAMPLING AT BOWLINE, 1981

	Median Length (mm)			
	Striped Bass		White Perch	
Week	Post Yolk-Sac Larvae	Juvenile	Post Yolk-Sac Larvae	Juvenile
5/10-16	--	--	--	--
5/17-23	6.6	--	3.7	--
5/24-30	6.7	--	3.5	--
5/31-6/6	7.8	--	3.1	--
6/7-13	9.2	--	--	--
6/14-20*	10.9	12.8	4.1	11.7
6/21-27	12.5	13.9	4.7	12.5
6/28-7/4	13.9	15.0	7.0	13.3
7/5-11	--	--	--	--
7/12-18	--	--	--	--
7/19-25	--	--	--	--
7/26-8/1	--	--	--	--
8/2-8	--	--	--	--
8/9-15	--	--	--	--
8/16-22*	--	--	--	--
8/23-29	--	--	--	--
8/30-9/5	--	--	--	--

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* No sampling. Estimate linear interpolation or extrapolation of two adjacent weeks' values.

TABLE C-9 WEEKLY ESTIMATES OF THE ACTUAL AND PROJECTED NUMBER OF STRIPED BASS EGGS AND YOLK-SAC LARVAE CROPPED BY ENTRAINMENT AT BOWLINE DURING 1981

EGGS

WEEK	ACTUAL UNIT 1	ACTUAL UNIT 2	ACTUAL TOTAL	PROJECTED TOTAL
5/10-5/16				
5/17-5/23				
5/24-5/30				
5/31-6/01				
6/07-6/13				
6/14-6/20				
6/21-6/27				
6/28-7/04				
7/05-7/11		NONE COLLECTED		
7/12-7/18				
7/19-7/25				
7/26-8/01				
8/02-8/08				
8/09-8/15				
8/16-8/22				
8/23-8/29				
8/30-9/05				
Total				

YOLK-SAC LARVAE

WEEK	ACTUAL UNIT 1	ACTUAL UNIT 2	ACTUAL TOTAL	PROJECTED TOTAL
5/10-5/16	0	0	0	0
5/17-5/23	1,847	0	1,847	3,693
5/24-5/30	0	0	0	0
5/31-6/01	547	397	944	1,384
6/07-6/13	0	0	0	0
6/14-6/20	0	0	0	0
6/21-6/27	0	0	0	0
6/28-7/04	0	0	0	0
7/05-7/11	0	0	0	0
7/12-7/18	0	0	0	0
7/19-7/25	0	0	0	0
7/26-8/01	0	0	0	0
8/02-8/08	0	0	0	0
8/09-8/15	0	0	0	0
8/16-8/22	0	0	0	0
8/23-8/29	0	0	0	0
8/30-9/05	0	0	0	0
Total	2,394	397	2,791	5,077

TABLE C-10 WEEKLY ESTIMATES OF THE ACTUAL AND PROJECTED NUMBER OF STRIPED BASS POST YOLK-SAC LARVAE AND EARLY JUVENILES CROPPED BY ENTRAINMENT AT BOWLINE DURING 1981

POST YOLK SAC LARVAE

WEEK	ACTUAL UNIT 1	ACTUAL UNIT 2	ACTUAL TOTAL	PROJECTED TOTAL
5/10-5/16	0	0	0	0
5/17-5/23	1,046	0	1,046	2,091
5/24-5/30	7,943	3,594	11,537	16,214
5/31-6/01	81,403	59,065	140,468	205,889
6/07-6/13	284,439	0	284,439	568,878
6/14-6/20	136,855	69,246	206,101	338,877
6/21-6/27	0	34,853	34,853	69,706
6/28-7/04	237	1,354	1,591	3,182
7/05-7/11	0	0	0	0
7/12-7/18	0	0	0	0
7/19-7/25	0	0	0	0
7/26-8/01	0	0	0	0
8/02-8/08	0	0	0	0
8/09-8/15	0	0	0	0
8/16-8/22	0	0	0	0
8/23-8/29	0	0	0	0
8/30-9/05	0	0	0	0
Total	511,923	168,112	680,035	1,204,837

EARLY JUVENILES

WEEK	ACTUAL UNIT 1	ACTUAL UNIT 2	ACTUAL TOTAL	PROJECTED TOTAL
5/10-5/16	0	0	0	0
5/17-5/23	0	0	0	0
5/24-5/30	0	0	0	0
5/31-6/01	0	0	0	0
6/07-6/13	0	0	0	0
6/14-6/20	1,610	3,181	4,791	10,661
6/21-6/27	0	10,237	10,237	20,474
6/28-7/04	477	2,723	3,200	6,400
7/05-7/11	0	0	0	0
7/12-7/18	0	0	0	0
7/19-7/25	0	0	0	0
7/26-8/01	0	0	0	0
8/02-8/08	0	0	0	0
8/09-8/15	0	0	0	0
8/16-8/22	0	0	0	0
8/23-8/29	0	0	0	0
8/30-9/05	0	0	0	0
Total	2,087	16,141	18,228	37,535

TABLE C-11 WEEKLY ESTIMATES OF THE ACTUAL AND PROJECTED NUMBER OF WHITE PERCH EGGS AND YOLK-SAC LARVAE CROPPED BY ENTRAINMENT AT BOWLINE DURING 1981

EGGS

WEEK	ACTUAL UNIT 1	UNIT 2	TOTAL	PROJECTED TOTAL
5/10-5/16	0	0	0	0
5/17-5/23	57,947	0	57,947	115,895
5/24-5/30	14,266	6,455	20,721	29,121
5/31-6/01	5,746	4,169	9,915	14,5335
6/07-6/13	4,1882	0	4,883	9,767
6/14-6/20	6,103	1,609	7,712	13,720
6/21-6/27	0	1,697	1,603	3,395
6/28-7/04	114	648	762	1,524
7/05-7/11	0	0	0	0
7/12-7/18	0	0	0	0
7/19-7/25	0	0	0	0
7/26-8/01	0	0	0	0
8/02-8/08	0	0	0	0
8/09-8/15	0	0	0	0
8/16-8/22	0	0	0	0
8/23-8/29	0	0	0	0
8/30-9/05	0	0	0	0
Total	89,059	14,578	103,637	187,955

YOLK-SAC LARVAE

WEEK	ACTUAL UNIT 1	UNIT 2	TOTAL	PROJECTED TOTAL
5/10-5/16				
5/17-5/23				
5/24-5/30				
5/31-6/01				
6/07-6/13				
6/14-6/20				
6/21-6/27				
6/28-7/04				
7/05-7/11	NONE COLLECTED			
7/12-7/18				
7/19-7/25				
7/26-8/01				
8/02-8/08				
8/09-8/15				
8/16-8/22				
8/23-8/29				
8/30-8/05				
Total				

TABLE C-12 WEEKLY ESTIMATES OF THE ACTUAL AND PROJECTED NUMBER OF WHITE PERCH POST YOLK-SAC LARVAE AND EARLY JUVENILES CROPPED BY ENTRAINMENT AT BOWLINE DURING 1981

POST YOLK-SAC LARVAE

		ACTUAL		PROJECTED
WEEK	UNIT 1	UNIT 2	TOTAL	TOTAL
5/10-5/16	0	0	0	0
5/17-5/23	40,033	0	40,033	80,067
5/24-5/30	89,864	35,070	124,934	186,417
5/31-6/01	26,334	19,908	45,442	66,606
6/07-6/13	0	0	0	0
6/14-6/20	7,949	3,974	11,923	19,638
6/21-6/27	0	10,672	10,672	21,345
6/28-7/04	1,549	8,831	10,380	20,760
7/05-7/11	0	0	0	0
7/12-7/18	0	0	0	0
7/19-7/25	0	0	0	0
7/26-8/01	0	0	0	0
8/02-8/08	0	0	0	0
8/09-8/15	0	0	0	0
8/16-8/22	0	0	0	0
8/23-8/29	0	0	0	0
8/30-9/05	0	0	0	0
Total	165,729	77,655	243,384	394,833

EARLY JUVENILES

		ACTUAL		PROJECTED
WEEK	UNIT 1	UNIT 2	TOTAL	TOTAL
5/10-5/16	0	0	0	0
5/17-5/23	0	0	0	0
5/24-5/30	0	0	0	0
5/31-6/01	0	0	0	0
6/07-6/13	0	0	0	0
6/14-6/20	0	4,601	10,009	15,145
6/21-6/27	0	14,134	14,134	28,267
6/28-7/04	753	4,296	5,049	10,099
7/05-7/11	0	0	0	0
7/12-7/18	0	0	0	0
7/19-7/25	0	0	0	0
7/26-8/01	0	0	0	0
8/02-8/08	0	0	0	0
8/09-8/15	0	0	0	0
8/16-8/22	0	0	0	0
8/23-8/29	0	0	0	0
8/30-9/05	0	0	0	0
Total	6,161	23,031	29,192	53,511

TABLE C-13 WEEKLY ESTIMATES OF THE ACTUAL AND PROJECTED NUMBER OF CLUPEID EGGS AND YOLK-SAC LARVAE CROPPED BY ENTRAINMENT AT BOWLINE DURING 1981

EGGS

		ACTUAL		PROJECTED
WEEK	UNIT 1	UNIT 2	TOTAL	TOTAL
5/10-5/16	31,379	0	31,379	62,759
5/17-5/23	0	0	0	0
5/24-5/30	0	0	0	0
5/31-6/01	0	0	0	0
6/07-6/13	0	0	0	0
6/14-6/20	0	0	0	0
6/21-6/27	0	0	0	0
6/28-7/04	0	0	0	0
7/05-7/11	0	0	0	0
7/12-7/18	0	0	0	0
7/19-7/25	0	0	0	0
7/26-8/01	0	0	0	0
8/02-8/08	0	0	0	0
8/09-8/15	0	0	0	0
8/16-8/22	0	0	0	0
8/23-8/29	0	0	0	0
8/30-9/05	0	0	0	0
Total	31,379	0	31,379	62,759

YOLK-SAC LARVAE

		ACTUAL		PROJECTED
WEEK	UNIT 1	UNIT 2	TOTAL	TOTAL
5/10-5/16				
5/17-5/23				
5/24-5/30				
5/31-6/01				
6/07-6/13				
6/14-6/20				
6/21-6/27				
6/28-7/04				
7/05-7/11		NONE COLLECTED		
7/12-7/18				
7/19-7/25				
7/26-8/01				
8/02-8/08				
8/09-8/15				
8/16-8/22				
8/23-8/29				
8/30-8/05				
Total				

TABLE C-14 WEEKLY ESTIMATES OF THE ACTUAL AND PROJECTED NUMBER OF CLUPEID POST YOLK-SAC LARVAE AND EARLY JUVENILES CROPPED BY ENTRAINMENT AT BOWLINE DURING 1981

POST YOLK-SAC LARVAE

WEEK	ACTUAL UNIT 1	UNIT 2	TOTAL	PROJECTED TOTAL
5/10-5/16	9,806	0	9,806	19,612
5/17-5/23	220,978	0	220,978	441,956
5/24-5/30	124,892	56,512	181,404	254,933
5/31-6/01	53,016	38,368	91,484	134,091
6/07-6/13	60,797	0	60,797	121,595
6/14-6/20	18,410	21,517	39,927	57,070
6/21-6/27	0	0	0	0
6/28-7/04	0	0	0	0
7/05-7/11	0	0	0	0
7/12-7/18	0	0	0	0
7/19-7/25	0	0	0	0
7/26-8/01	0	0	0	0
8/02-8/08	0	0	0	0
8/09-8/15	0	0	0	0
8/16-8/22	0	0	0	0
8/23-8/29	0	0	0	0
8/30-9/05	0	0	0	0
Total	487,899	116,497	604,396	1,029,257

EARLY JUVENILES

WEEK	ACTUAL UNIT 1	UNIT 2	TOTAL	PROJECTED TOTAL
5/10-5/16	0	0	0	0
5/17-5/23	0	0	0	0
5/24-5/30	0	0	0	0
5/31-6/01	0	0	0	0
6/07-6/13	0	0	0	0
6/14-6/20	0	0	0	0
6/21-6/27	0	0	0	0
6/28-7/04	0	0	0	0
7/05-7/11	15,674	11,034	26,709	31,349
7/12-7/18	36,172	36,172	72,343	72,343
7/19-7/25	0	0	0	0
7/26-8/01	0	0	0	0
8/02-8/08	0	0	0	0
8/09-8/15	12,057	8,408	20,465	24,114
8/16-8/22	0	0	0	0
8/23-8/29	0	0	0	0
8/30-8/05	0	0	0	0
Total	63,903	55,614	119,517	127,806

TABLE C-15 WEEKLY ESTIMATES OF THE ACTUAL AND PROJECTED NUMBER OF BAY ANCHOVY EGGS AND YOLK-SAC LARVAE CROPPED BY ENTRAINMENT AT BOWLINE DURING 1981

EGGS

WEEK	ACTUAL UNIT 1	UNIT 2	TOTAL	PROJECTED TOTAL
5/10-5/16	0	0	0	0
5/17-5/23	0	0	0	0
5/24-5/30	0	0	0	0
5/31-6/01	0	0	0	0
6/07-6/13	0	0	0	0
6/14-6/20	0	0	0	0
6/21-6/27	0	0	0	0
6/28-7/04	0	0	0	0
7/05-7/11	0	0	0	0
7/12-7/18	88,018	88,018	176,036	176,036
7/19-7/25	0	0	0	0
7/26-8/01	0	0	0	0
8/02-8/08	0	0	0	0
8/09-8/15	0	0	0	0
8/16-8/22	0	0	0	0
8/23-8/29	0	0	0	0
8/30-9/05	0	0	0	0
Total	88,018	88,018	176,036	176,036

YOLK-SAC LARVAE

WEEK	ACTUAL UNIT 1	UNIT 2	TOTAL	PROJECTED TOTAL
5/10-5/16				
5/17-5/23				
5/24-5/30				
5/31-6/01				
6/07-6/13				
6/14-6/20				
6/21-6/27				
6/28-7/04				
7/05-7/11		NONE COLLECTED		
7/12-7/18				
7/19-7/25				
7/26-8/01				
8/02-8/08				
8/09-8/15				
8/16-8/22				
8/23-8/29				
8/30-8/05				
Total				

TABLE C-16 WEEKLY ESTIMATES OF THE ACTUAL AND PROJECTED NUMBER OF BAY ANCHOVY POST YOLK-SAC LARVAE AND EARLY JUVENILES CROPPED BY ENTRAINMENT AT BOWLINE DURING 1981

POST YOLK-SAC LARVAE

	ACTUAL			PROJECTED
WEEK	UNIT 1	UNIT 2	TOTAL	TOTAL
5/10-5/16	0	0	0	0
5/17-5/23	0	0	0	0
5/24-5/30	0	0	0	0
5/31-6/01	4,678	3,394	8,072	11,832
6/07-6/13	0	0	0	0
6/14-6/20	154,645	180,744	335,390	479,390
6/21-6/27	0	5,237,084	5,237,084	10,474,167
6/28-7/04	1,161,455	6,623,238	7,784,699	15,569,398
7/05-7/11	2,913,027	2,050,665	4,963,691	5,816,054
7/12-7/18	12,796,338	12,796,338	25,592,687	25,592,676
7/19-7/25	7,985,503	7,985,503	15,971,013	15,971,007
7/26-8/01	5,329,129	12,434,621	17,763,751	24,869,243
8/02-8/08	1,415,518	9,634,635	11,050,161	19,615,692
8/09-8/15	10,956,04	7,640,259	18,596,673	21,912,810
8/16-8/22	7,864,324	1,196,593	9,060,923	15,728,647
8/23-8/29	6,403,595	0	6,403,595	12,807,190
8/30-9/05	1,283,431	1,794,772	3,078,203	4,497,347
Total	58,268,048	67,577,846	125,845,942	173,355,453

EARLY JUVENILES

	ACTUAL			PROJECTED
WEEK	UNIT 1	UNIT 2	TOTAL	TOTAL
5/10-5/16	0	0	0	0
5/17-5/23	0	0	0	0
5/24-5/30	0	0	0	0
5/31-6/01	0	0	0	0
6/07-6/13	0	0	0	0
6/14-6/20	0	0	0	0
6/21-6/27	0	0	0	0
6/28-7/04	0	0	0	0
7/05-7/11	0	0	0	0
7/12-7/18	3,617	3,617	7.234	7.234
7/19-7/25	60,286	60,286	120,572	120,572
7/26-8/01	23,253	54,258	77,511	108,515
8/02-8/08	8,785	59,791	68,576	121,733
8/09-8/15	356,894	248,874	605,768	713,788
8/16-8/22	118,865	18,086	136,951	237,730
8/23-8/29	44,612	0	44,612	89,224
8/30-9/05	105,978	148,201	254,179	371,363
Total	722,290	593,113	1,315,403	1,770,159

APPENDIX D

DATA USED FOR ANALYSIS OF RELATIONSHIP BETWEEN SURVIVAL OF YOUNG OF THE YEAR IMPINGED FISH AT THE BOWLINE POINT PLANT AND PHYSICO-CHEMICAL VARIABLES 1975-1981

LIST OF TABLES

TABLE D-1 DATA USED FOR ANALYSIS OF RELATIONSHIP BETWEEN SURVIVAL OF YOUNG OF THE YEAR WHITE PERCH IMPINGED AT THE BOWLINE POINT PLANT AND PHYSICO-CHEMICAL VARIABLES 1975-1981

OBS	Serial Number	Average Temp (C)	Average Cond. (μmhos/cm)	Total Number	Number Live at 108 hrs.	Percent Survival 108 hrs.
1	BABDE002	25.9	8799	33	32	96.970
2	BABDE003	24.8	4867	140	103	73.571
3	BABDE004	21.4	3145	10	7	70.000
4	BABDE009	7.6	667	42	22	52.381
5	BABDE010	5.4	226	32	4	12.500
6	BABDE012	1.3	1876	18	7	38.889
7	BABDE013	0.2	2778	171	123	71.930
8	BABDE014	-0.6	6817	11	4	36.364
9	BABDE015	-0.9	6394	71	47	66.197
10	BABDE016	0.5	4560	142	99	69.718
11	BABDE017	3.6	182	91	22	24.176
12	BABDE018	8.0	138	84	21	25.000
13	BABDE019	11.6	795	88	36	40.909
14	BABDE025	26.1	7633	101	75	74.257
15	BABDE028	24.3	10642	15	15	100.000
16	BABDE636	4.4	3127	34	31	91.176
17	BABDE637	2.2	2260	67	35	52.239
18	BABDP017	3.6	181	47	17	36.170
19	BCBDE601	0.3	6645	63	53	84.127
20	BCBDE602	2.8	3246	357	282	78.992
21	BCBDE603	4.0	1408	138	77	55.797
22	BCBDE604	3.2	1911	308	141	45.779
23	BCBDE605	5.0	2138	422	143	33.886
24	BCBDE606	7.0	2974	150	107	71.333
25	BCBDE607	9.5	850	533	226	42.402
26	BSI001	9.7	195	16	4	25.000
27	BSI002	9.7	195	10	2	20.000
28	BSI003	9.6	196	22	3	13.636
29	BSI004	9.7	199	14	0	0.000
30	BSI010	7.2	197	65	31	47.692
31	BSI011	7.0	190	24	9	37.500
32	BSI012	7.0	190	50	19	38.000
33	BSI013	7.0	190	20	10	50.000
34	BSI017	7.3	626	101	56	55.446
35	BSI018	7.2	680	242	165	68.182
36	BSI023	4.2	1670	71	46	64.789
37	BSI024	4.2	1670	70	45	64.286
38	BSI025	4.2	1691	73	62	84.932
39	BSI026	4.2	1691	68	56	82.353
40	BSI027	4.1	1684	72	62	86.111
41	BSI028	4.1	1681	65	46	70.769
42	BSI029	4.1	1697	74	37	50.000
43	BSI031	4.0	1692	64	41	64.063
44	BSI033	4.0	1679	61	41	67.213
45	BSI040	3.4	1105	70	63	90.000
46	BSI042	3.4	1124	60	52	86.667

TABLE D-1 CONT.

OBS	Serial Number	Average Temp (C)	Average Cond. (μmhos/cm)	Total Number	Number Live at 108 hrs.	Percent Survival 108 hrs.
47	BSI044	3.4	1139	59	38	64.407
48	BSI046	4.4	1174	65	37	56.923
49	BSI047	4.4	1174	56	47	83.929
50	BSI048	4.4	1176	69	60	86.956
51	BSI049	4.4	1176	59	58	98.305
52	BSI050	4.4	1177	64	37	57.812
53	BSI051	4.4	1177	45	36	80.000
54	BSI057	2.0	531	63	7	11.111
55	BSI058	2.0	531	63	2	3.175
56	BSI059	1.9	531	69	9	13.043
57	BSI060	1.9	531	60	2	3.333
58	BSI061	1.9	522	61	10	16.393
59	BSI062	1.9	526	54	4	7.407
60	BSI063	1.8	661	66	7	10.606
61	BSI064	1.8	659	63	20	31.746
62	BSI065	1.8	658	68	29	42.647
63	BS2001	1.7	3586	141	7	4.964
64	BS2002	0.8	3822	27	2	7.407
65	BS2003	0.8	3822	15	6	40.000
66	BS2004	0.9	3818	17	2	11.765
67	BS2006	0.9	3775	10	1	10.000
68	BS2010	0.7	1923	25	5	20.000
69	BS2011	1.9	1923	12	4	33.333
70	BS2012	0.7	1944	35	5	14.286
71	BS2013	1.6	1944	49	13	26.531
72	BS2014	1.5	1941	28	3	10.714
73	BS2015	0.6	1941	32	5	15.625
74	BS2016	0.7	1970	10	1	10.000
75	BS2017	0.7	1970	14	3	21.429
76	BS2018	0.7	1971	20	3	15.000
77	BS2019	2.2	2149	42	4	9.524
78	BS2020	1.8	2148	43	7	16.279
79	BS2021	1.5	2090	48	10	20.833
80	BS2022	1.6	2071	101	12	11.881
81	BS2023	1.6	2071	49	8	16.326
82	BS2024	1.9	2074	96	23	23.958
83	BS2025	1.9	2074	80	13	16.250
84	BS2026	1.7	2009	78	8	10.256
85	BS2027	1.7	2013	62	28	45.161
86	BS2028	2.7	1459	49	5	10.204
87	BS2029	2.7	1459	14	4	28.571
88	BS2030	2.6	1451	42	13	30.952
89	BS2031	2.7	1536	36	5	13.889
90	BS2032	2.7	1562	34	11	32.353
91	BS2033	2.7	1562	43	17	39.535
92	BS2034	3.3	1444	74	32	43.243
93	BS2035	3.0	1463	248	107	43.145
94	BS2036	3.3	1465	191	61	31.937

TABLE D-1 CONT

OBS	Serial Number	Average Temp (C)	Average Cond. (µmhos/cm)	Total Number	Number Live at 108 hrs.	Percent Survival 108 hrs.
95	BS2042	4.7	150	10	0	0.000
96	BS2048	4.9	140	16	1	6.250
97	BS2050	7.6	134	60	5	8.333
98	BS2052	7.5	125	29	2	6.897
99	BS2053	3.7	2460	46	28	60.870
100	BS2054	3.5	2404	17	11	64.706
101	BS2063	3.7	680	98	36	36.735
102	BS2064	3.4	661	195	72	36.923
103	BS3001	1.2	605	13	0	0.000
104	BS3002	1.5	1595	160	58	36.250
105	BS3005	1.3	173	63	7	11.111
106	BS3008	1.2	355	14	1	7.143
107	BS3009	1.2	355	17	2	11.765
108	BS3015	6.6	166	234	25	10.684
109	BS3018	8.8	187	26	5	19.231
110	BS3021	8.4	3615	232	225	96.983
111	BS3024	11.1	718	165	93	56.364
112	ISB001	5.7	1013	10	9	90.000
113	ISB002	5.7	1013	88	84	95.454
114	ISB005	2.9	309	29	10	34.483
115	ISB007	8.1	199	34	2	5.882
116	ISB008	10.4	976	71	48	67.606

TABLE D-2 DATA USED FOR ANALYSIS OF THE RELATIONSHIP BETWEEN SURVIVAL OF YOUNG OF THE YEAR STRIPED BASS IMPINGED AT THE BOWLINE POINT PLANT AND PHYSICO-CHEMICAL VARIABLES, 1975-1981

OBS	Serial Number	Average Temp (C)	Average Cond. (µmhos/cm)	Total Number	Number Live at 108 hrs.	Survival Proportion 108 hrs.
1	BCBDE601	0.3	6645	27	19	0.704
2	BCBDE604	3.2	1911	308	139	0.451
3	BSI044	3.4	1139	11	11	1.000
4	BSI046	4.4	1174	10	3	0.300
5	BSI047	4.4	1174	10	10	1.000
6	BSI049	4.4	1176	11	11	1.000
7	BSI051	4.4	1177	16	13	0.812
8	BSI057	2.0	531	11	2	0.182
9	BSI059	1.9	531	19	2	0.105
10	BSI061	1.9	522	18	4	0.222
11	BSI062	1.9	526	10	2	0.200
12	BSI063	1.8	661	14	1	0.071
13	BS2001	1.7	3586	25	4	0.160
14	BS2010	0.7	1923	11	1	0.090
15	BS2012	0.7	1944	20	4	0.200
16	BS2016	0.7	1970	20	2	0.100
17	BS2018	0.7	1971	12	0	0.000
18	BS2019	2.2	2149	16	3	0.187
19	BS2020	1.8	2148	25	2	0.080
20	BS2021	1.5	2090	16	6	0.375
21	BS2022	1.6	2071	24	10	0.417
22	BS2024	1.9	2074	28	7	0.250
23	BS2026	1.7	2009	51	2	0.039
24	BS2027	1.7	2013	11	5	0.455
25	BS2028	2.7	1459	13	1	0.077
26	BS2030	2.6	1451	15	4	0.267
27	BS2032	2.7	1562	15	11	0.733
28	BS2034	3.3	1444	31	20	0.645
29	BS2035	3.0	1463	110	39	0.355
30	BS2036	3.3	1465	77	32	0.416
31	BS3002	1.5	1595	12	4	0.333
32	ISB005	2.9	309	30	3	0.100
33	BCBDE605	5.0	2138	224	70	0.312
34	BCBDE606	7.0	2974	26	18	0.692
35	BCBDE607	9.5	850	45	22	0.489
36	BS3015	6.6	166	72	1	0.014
37	BS3018	8.8	187	19	0	0.000
38	BS3021	8.4	3615	28	15	0.536
39	BS3024	11.1	718	19	6	0.316

BOWLINE POINT GENERATING STATION
316(a) DEMONSTRATION
MARCH 1978

O
YOUR ENERGY PEOPLE
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ORANGE AND ROCKLAND UTILITIES, INC.

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BOWLINE POINT GENERATING STATION
316(a) DEMONSTRATION

Orange and Rockland Utilities, Inc.
One Bluehill Plaza
Pearl River, New York 10965

March 1978

CONTENTS

CONTENTS

LIST OF TABLES

LIST OF TABLES (CONT.)

LIST OF FIGURES

LIST OF FIGURES (CONT.)

LIST OF FIGURES (CONT.)

PREFACE

PREFACE

Orange and Rockland Utilities, Inc. hereby submits this demonstration to the United States Environmental Protection Agency (EPA) pursuant to Section 316(a) of the Federal Water Pollution Control Act as amended, 33 U.S.C. Section 1326a, and the proposed National Pollutant Discharge Elimination System (NPDES) Permit No. NY0008010 for the Bowline Point Generating Station.

This demonstration shows that the effluent limitations for the Bowline Point plant, as specified in this proposed NPDES permit, are more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the Hudson River estuary. In accordance with Orange and Rockland's 316(a) plan of study and demonstration submitted to EPA Region II on 2 July 1976, and subsequently approved by written authorization on 22 December 1976, this is a Type III demonstration, in that it incorporates aspects of both Type I (nonpredictive) and Type II (predictive) demonstrations to evaluate the possible effects of the Bowline Point plant's thermal discharge. The information presented herein has been organized so that a single volume presents a summary of pertinent data relating to the hydrothermal analyses of the discharge (Chapter 3), and an evaluation of the effects, if any, of the discharge on specific biotic (trophic level) categories (Chapter 4) and representative import species (Chapter 5). A synthesis of the key facts and evidence which demonstrate that continued use of once-through cooling at the Bowline Point plant will not alter the balanced, indigenous biological community in and on the Hudson River estuary is presented in the Master Rationale (Chapter 2). Additionally, the costs versus benefits of implementing and operating a closed-cycle cooling system at the Bowline Point plant are addressed in Chapter 6.

The basic format and content of this demonstration follow recommendations of the current 1 May 1977 draft of the EPA "316(a) Technical Guidance Manual" where appropriate.

Documents which are part of the record in Docket II-C/WP-77-1, the consolidated adjudicatory hearing for the major Hudson River electric generating stations, are referred to in this demonstration. Such references incorporate any supplements, additions, or errata which have been introduced in such proceeding with regard to the specific documents identified herein.

Chapter 1
INTRODUCTION

CHAPTER 1: INTRODUCTION

1.1 BOWLINE POINT GENERATING STATION

The Bowline Point Generating Station is located on the west bank of the Hudson River near Haverstraw, New York, approximately 37.5 mi north of the river mouth at the Battery in New York City. The location of the plant in relation to other electric generating stations on the Hudson River estuary is shown in Figure 1.1-1.

Orange and Rockland Utilities, Inc. and Consolidated Edison Company of New York (Con Edison) own the Bowline Point plant as tenants in common, with ownership of one third and two thirds, respectively. Orange and Rockland, on behalf of the tenants in common, arranged for, supervised, and effectuated the design and construction of the plant which it now operates and maintains.

The Bowline Point plant consists of two 600 MWe (rated net generating capacity) oil- and gas-fired steam-electric units; Unit 1 has been in operation since September 1972 and Unit 2 began commercial operation in May 1974. Each unit has a separate once-through cooling water system that transfers waste heat from the condensers to the Hudson River. Cooling water for each unit is drawn from Bowline Pond, which is connected with the Hudson River by a shallow inlet permitting a free exchange of river water, and discharged back into the river through separate offshore diffusers.

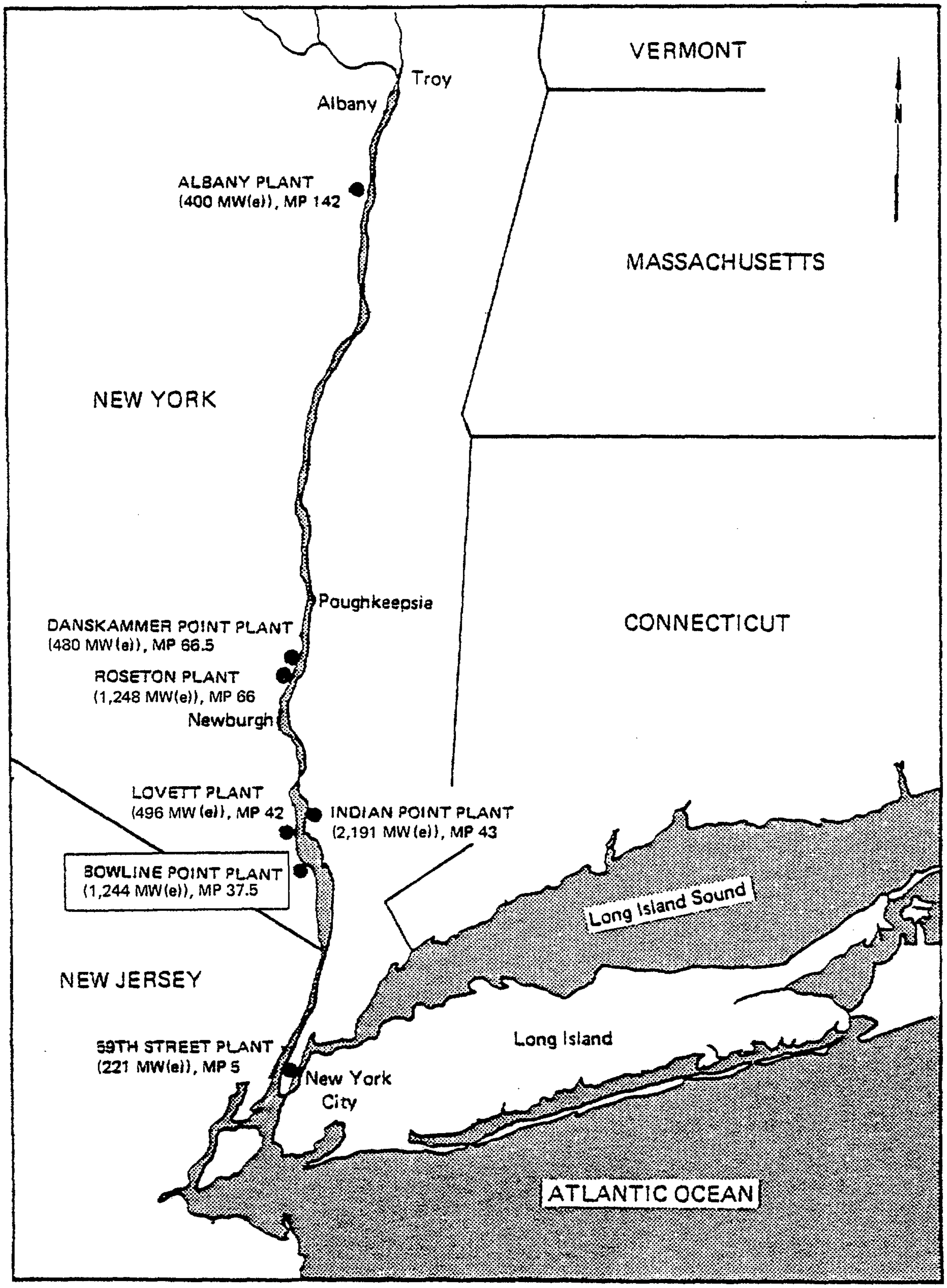

Figure 1.1-1. Location of the Bowline Point plant in relation to other generating stations on the Hudson River Estuary (Scale: 1:1,267,200) (adapted from ORU 1977).

1.2 REGULATORY REQUIREMENTS AFFECTING THE BOWLINE POINT GENERATING STATION'S THERMAL DISCHARGE

1.2.1 Background

Current legislation affecting the discharge of heat by open-cycle electrical generating facilities, such as the Bowline Point Generating Station, is contained in the Federal Water Pollution Control Act as amended (the Act). The primary purpose of the Act is to provide for the maintenance of the chemical, physical, and biological integrity of the nation's waters. Of particular concern to the electrical utility industry is the fact that, under the Act, heat or the thermal component of a discharge (such as power plant condenser cooling water) is classified as a pollutant to be controlled.

The United States Environmental Protection Agency (EPA) has the responsibility for administering the Act and is empowered by the Act to grant National Pollutant Discharge Elimination System (NPDES) permits for certain discharges, under conditions or limitations to be stated in the permits. Section 316(a) of the Act, however, provides a mechanism for modification of thermal effluent limitations in certain cases. In accordance with the specifications of Section 316(a), EPA has the authority to impose less stringent effluent limitations for the control of the thermal component of any discharge if the owner or operator of the discharge source can satisfactorily demonstrate to the EPA administrator that existing limitations are more stringent than necessary "...to assure the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife in and on the body of water into which the discharge is made."

1.2.2 History of Regulatory Proceedings

On 15 November 1971, before the Bowline Point plant became operational and prior to the enactment of the Act, Orange and Rockland Utilities filed an application with the United States Army Corps of Engineers for a discharge permit under the "Refuse Act."* When the Act became effective on 18 October 1972,** this application automatically became an application to the EPA for an NPDES permit.

On 24 May 1974, 19 months later, EPA Region II sent Orange and Rockland a "draft" NPDES permit that required the virtual elimination of the discharge of heat which would effectively require the construction of one cooling tower for each unit at the Bowline Point plant. Orange and Rockland requested an adjudicatory hearing upon this "draft" permit on 28 June 1974, and applied for alternative effluent limitations pursuant to Section 316(a) of the Act. On 28 July 1974, Orange and Rockland submitted to EPA Region II preliminary 316(a) demonstration information which was then available.

Orange and Rockland received a proposed NPDES permit from EPA Region II on 25 February 1975. This proposed permit also effectively required cooling tower installation (by 1 July 1981).

On 14 March 1975, Orange and Rockland requested an adjudicatory hearing on the proposed permit, challenged the required reduction of the thermal discharge, and again requested alternative effluent limitations under Section 316(a) of the Act. Orange and Rockland's request for an adjudicatory hearing was granted by EPA Region II on 20 June 1975.

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* 33 U.S.C. Section 407.

** 33 U.S.C. Sections 1251-1376 (App. V 1975).

On 20 June 1975, Orange and Rockland and EPA Region II Staff held a meeting to discuss the representative important species (RIS) which would be involved in a 316(a) determination; EPA suggested that Orange and Rockland formally request that EPA designate the RIS. In accordance with this suggestion, a formal request by Orange and Rockland was filed with EPA Region II on 10 February 1976. Acting pursuant to Section 316(a) of the Act and 40 CFR 122.9 (b) (ii) (A), on 3 May 1976 EPA designated the RIS (Table 1.2-1) and required Orange and Rockland to submit within 60 days a plan of study and demonstration. Orange and Rockland submitted this RIS plan of study to EPA Region II on 2 July 1976.

On 30 November 1976, Orange and Rockland was advised orally by EPA Region II that the plan of study had been approved. Formal written approval followed on 22 December 1976; this approval required Orange and Rockland to submit: (1) a status report within 2 months; (2) a progress report within 12 months of the initiation of 316(a) studies; and (3) a final "Type III demonstration" by 31 March 1978. Pursuant to this schedule, Orange and Rockland filed on 7 March 1977 its first status report entitled "Hudson River Thermal Effects Studies for Representative Species" (January 1977), and on 13 July 1977 Orange and Rockland's second progress report was submitted. The present report is submitted in compliance with the schedule specified by EPA Region II as Orange and Rockland's 316(a) demonstration.

1.2.3 Regulatory Proceedings Pertaining to Cost-Benefit Analysis for Closed-Cycle Cooling

The effluent limitations applied to the thermal component of the Bowline Point plant's cooling water discharge by the Tentative Determinations of EPA Region II were based on Effluent Guidelines and Standards for the Steam Electric

TABLE 1.2-1 REPRESENTATIVE IMPORTANT SPECIES FOR THE BOWLINE POINT GENERATING STATION, AS DESIGNATED BY THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, 3 MAY 1976

Common Name	Scientific Name
Fish	
Alewife	*Alosa pseudoharengus*
Atlantic sturgeon	*Acipenser oxyrhynchus*
Atlantic tomcod	*Microgadus tomcod*
Bay anchovy	*Alosa mitchilli*
Shortnose sturgeon	*Acipenser brevirostrum*
Spottail shiner	*Notropis hudsonius*
Striped bass	*Morone saxatilis*
Weakfish	*Cynoscion regalis*
White catfish	*Ictalurus catus*
White perch	*Morone americana*
Macroinvertebrates	
Amphipod	*Gammarus* spp.
Opossum shrimp	*Neomysis americana*
Sand shrimp	*Crangon septemspinosa*
Algae	
Blue-green	Cyanophyta

Power Generating Point Source Category issued on 8 October 1974 by EPA, 40 CFR Part 423. On 16 July 1976, these effluent guidelines and standards were remanded to EPA by the Court of Appeals, Fourth Circuit* for failure of EPA to satisfy certain statutory standards relating to the promulgation of such effluent guidelines and standards, including a failure to properly assess the costs and benefits of retrofitting closed-cycle cooling on existing plants. As a result of this decision, the basis for EPA Region II's effluent limitations for such thermal component contained in the Tentative Determinations has been rendered inapplicable and the General Counsel of EPA has ruled** that EPA Region II must develop effluent limitations for the Bowline Point plant's thermal discharge based on its authority under Section 402(a)(1) of the Act.

On 11 July 1977, a motion was filed on behalf of Orange and Rockland for a determination by the Regional Administrator, EPA Region II, of the best available technology economically achievable (BATEA) under Section 402(a) of the Act for certain electric generating stations on the Hudson River, including the Bowline Point plant. More specifically, this motion requested the Regional Administrator to establish effluent limitations applicable to the thermal component of the discharge from the Bowline Point plant. The Regional Administrator has not responded to this motion.

In keeping with the EPA Administrator's decision in the Seabrook case,*** the EPA General Counsel in his determination that EPA Region II develop effluent limitations for the Bowline Point plant's thermal discharge**

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* Appalachian Power Company versus Train, 545 F. 2d 1351 (4th Cir. 1976).

** Decision of the General Counsel on Matters of Law Pursuant to 40 CFR Section 125.36 (m), No. 63 (OGC #63).

*** Matter of Public Service Company of New Hampshire, Case 76-7, 17 June 1977, modified 9 November 1977.

held that the Regional Administrator must consider the factors set out in Sections 304(b)(1)(B) and 304(b)(2)(B) of the Act. These factors include whether the costs of the proposed technology to meet the effluent guidelines established under Section 402(a)(1) of the Act are disproportionate to the expected benefits.

As a result of this holding, the relationship of the costs and benfits of the technology necessary to meet the effluent limitations ultimately established for the Bowline Point plant by the Regional Administrator of EPA Region II are relevant to this 316(a) demonstration. Since the practicable technology available to meet the present (but invalidated) effluent limitations contained in the Tentative Determinations of EPA Region II is closed-cycle cooling towers, this demonstration incorporates by reference the cost-benefit analysis of cooling tower construction at the Bowline Point plant submitted in Docket No. II-C/WP-77-1 of the consolidated adjudicatory hearing for the major Hudson River electric generating stations. However, in the event that the Regional Administrator subsequently determines that a different technology represents BATEA for the Bowline Point plant, Orange and Rockland reserves its right to submit a demonstration regarding the costs versus the benefits of such technology.

1.3 316(a) DEMONSTRATION CONTENT AND SCOPE

1.3.1 Statement of Purpose

This report demonstrates, in accordance with Section 316(a) of the Federal Water Pollution Control Act Amendments of 1972 (the Act), that the thermal component of the cooling water discharge from the Bowline Point Generating Station, at present maximum net designed capability, does not interfere with the "...protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife..." in and on the Hudson River estuary. In so doing, this report provides a basis for Orange and Rockland Utilities' request for the imposition of a less stringent effluent limitation for the Bowline Point plant which would allow continued use of the existing once-through cooling system such that New York thermal criteria will be maintained.

1.3.2 Format and Approach

Although Orange and Rockland's approved 316(a) plan of study and demonstration for the Bowline Point plant was prepared on the basis of technical guidance recommendations set forth in the 30 September 1974 draft of the "EPA 316(a) Technical Guidance Manual" (EPA 1974), this demonstration has been developed, for the convenience of the regulatory reviewers, to closely conform to the format and information requirements suggested in the 1 May 1977 draft of this guidance manual (EPA 1977). Therefore, to the extent possible, this demonstration responds to EPA's most up-to-date 316(a) technical guidance recommendations.

The contents of this demonstration have been organized so that a single volume presents a summary of pertinent information on the hydrothermal analyses of the discharge (Chapter 3), and an evaluation of the effects of the discharge on specific biotic (trophic level) categories (Chapter 4) and representative important species (Chapter 5). A synthesis of the key facts and evidence which demonstrate that continued use of once-through cooling at the Bowline Point plant will assure the protection and propagation of the balanced, indigenous biological community in and on the Hudson River estuary is presented in the Master Rationale (Chapter 2). The costs versus benefits of implementing and operating a closed-cycle cooling system at the Bowline Point plant are addressed in Chapter 6.

In accordance with the approved 316(a) plan of study and demonstration for the Bowline Point plant, this is a Type III demonstration, in that it incorporates aspects of both Type I (nonpredictive) and Type II (predictive) demonstrations to evaluate the biological effects of the plant's thermal discharge. Specifically, assessment of impact of the thermal discharge upon major biotic categories (Chapter 4) is addressed primarily from the standpoint of a Type I approach; i.e., historical near- and far-field biological survey data are presented to demonstrate the absence of prior appreciable harm to the balanced, indigenous community. The predictive Type II approach is employed in presenting species-specific thermal effects and life history data (Chapter 5) to demonstrate that the protection and propagation of representative important species (RIS) will be assured.

The concept of the RIS approach is that rather than requesting an applicant seeking a 316(a) variance to produce exhaustive data on all organisms that occur within the vicinity of a particular discharge or discharges, appropriate species are identified which, "... if protected, will reasonably assure protection of other species at the site" (EPA 1977:p. 35). The RIS approach is based upon the biological rationale that the effects of thermal or other stresses on non-RIS species or groups of organisms can generally be inferred from the effects, if any, of such stresses on RIS species that have been specifically studied. Species selected as RIS are generally those that are known or thought to be important from the standpoint of economic value, role in the food-chain, dominance in terms of numerical abundance or wide distribution, threatened or endangered status, or thermal sensitivity (EPA 1977:pp. 36-38).

The overall approach of this 316(a) demonstration, i.e., the presentation of both predictive and nonpredictive evaluations of possible biological effects resulting from the Bowline Point plant's thermal discharge, is in keeping with the assessment that neither general ecosystem field surveys nor RIS laboratory studies are sufficient for predictive demonstrations, but that some mixture of the two is desirable (Coutant 1970:p. 376; EPA 1977:p. 7).

1.3.3 Evaluation Criteria

According to the 1 May 1977 draft of the EPA 316(a) Technical Guidance Manual (EPA 1977:pp. 70-71), a 316(a) demonstration will be judged successful if sufficient evidence is presented to support the following conclusions:

1. The balanced, indigenous community, or community components, have not sustained any prior appreciable harm.
2. Receiving water temperatures outside any state established mixing zone will not be in excess of the upper temperature limits for survival, growth, and reproduction, as applicable, of any representative important species (RIS) occurring in the receiving water.
3. A shift toward nuisance species in the receiving water is not likely to occur.

4. A zone of passage will not be impaired to the extent that it will not provide for the normal movement of populations of RIS, dominant species of fish, and economically important species of fish, shellfish, and wildlife.
5. There will be no adverse impact on threatened or endangered species.
6. There will be no destruction of rare or unique habitat.
7. The planned use of biocides such as chlorine will not result in appreciable harm to the balanced indigenous community.

These evaluation criteria are used, where applicable, to evaluate the effects of the Bowline Point Generating Station's thermal discharge (and other related stresses) on the overall well-being of the balanced, indigenous community of the Hudson River estuary. The primary emphasis in this demonstration as a whole, and the Master Rationale (Chapter 2) in particular, focuses on the implications of the first criteria; i.e., development of an "overall picture" of the ecosystem as projected by the separate biotic categories rationales (Chapter 4) and the predictive thermal effects rationales for RIS (Chapter 5) (EPA 1977:p. 52).

1.3.4 Information Sources*

During the past decade, studies conducted by numerous research groups (including government, university, and private consulting organizations) have compiled an extensive data base on the biota of the Hudson River estuary to

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* This subsection includes a brief overview of aquatic studies relating to Hudson River power plant operation. A more extensive summary on this topic, including the role of specific research organizations, can be found in McFadden 1977(pp. 1.12 - 1.30). Further information on the history and scope of studies at the Bowline Point plant is detailed in ORU 1977(pp. 1.2-1 - 1.2-6 and 1.3-1 - 1.3-7).

assess the biological effects of power plant operation. The first of these studies, a government-directed research program conducted from 1965 to 1968, sampled the estuary from Croton to Coxsackie, milepoints (MP) 35.5-125, to evaluate the effects of Consolidated Edison Company of New York's (Con Edison) proposed Cornwall pumped-storage generating facility (MP 56.5) on striped bass and other major fish species.

Studies were subsequently expanded in the early 1970s to respond to concerns relating to the biological effects of the operation of Con Edison's Indian Point Generating Station and other steam-electric power plants operating or coming online in the mid-Hudson area (Table 1.3-1). To gather the information necessary to evaluate the effects of power plant operation on fishery resources of the Hudson River estuary, Con Edison began a comprehensive study program in 1973 to define the distribution and abundance of various life stages of Hudson River fish species from the George Washington Bridge (MP 12) to the Troy Dam (MP 152). As a result of interest relating to the operational effects of Orange and Rockland's Bowline Point Generating Station and Central Hudson Gas & Electric Corporation's Roseton and Danskammer Point Generating Stations, these utilities began joint participation in this sampling program with Con Edison in 1974. To date, this program, which has become known as the Multiplant Impact Study, has been ongoing for a period of 5 years and is scheduled for continuation in 1978.

In addition to the total system approach of the Multiplant Impact Study, the Hudson River utilities have conducted intensive site-specific (near-field) studies in the area of each power plant. In the vicinity of the Bowline Point and Indian Point plants (i.e., MP 35-43) biological surveys to define the local distribution, abundance, and species composition of various trophic lev-

TABLE 1.3-1 CHARACTERISTICS AND DATE OF COMMERCIAL OPERATION OF POWER PLANTS LOCATED ON THE HUDSON RIVER ESTUARY(a)

Power Plant (Owner)	Type of Power Plant	Location (River Mile)	Generating Unit No.	Gross Rated Capacity (MWe)	Cooling Water Flow (gal min^{-1})	Plant Temperature Rise (F)	Waste Heat (BB day^{-1})	Type of Discharge Structural	Date of Commercial Operation
Albany Steam Station	Fossil	142.0	1	100	88,000	10.3	10.9	Surface discharge	11/16/52
(Niagara Mohawk	fuel	West bank	2	100	88,000	10.3	10.9	common to all	12/14/52
Power Corp.)			3	100	88,000	10.3	10.9	generating units	10/01/53
			4	100	88,000	10.3	10.9		09/10/54
			Total	400	352,000	10.3	43.6		
Danskammer Point	Fossil	66.5	1	41	42,000	17.0	8.6		12/31/51
(Central Hudson Gas	fuel	West bank	2	69	42,000	17.0	8.6	Surface discharge	09/14/54
and Electric Corp.)			3	127	82,000	17.0	16.7		10/15/59
			4	243	150,000	17.0	30.6		09/15/67
			Total	480(b)	316,000	17.0	64.5		
Roseton	Fossil	66.0	1	624	320,500	17.8	68.6	Submerged diffuser	12/74
(Central Hudson Gas	fuel	West bank	2	624	320,500	17.8	68.6	common to both	09/74
and Electric Corp.)(c)			Total	1,248	641,000	17.8	137.2	units	
Indian Point	Nuclear(d)	43.0							
(Consolidated Edison		East bank	1	285	318,000(e)	(f)	(f)	Submerged near-	09/30/62
Company of New York,			2	906	870,000(e)	15.8	156	surface discharge	10/73(g)
Inc.)			3(h)	1,000	870,000(e)	17.1	173	common to all units	08/30/76
			Total	2,191	2,058,000(e)	16.5	329		
Lovett	Fossil	42.0	1	19	25,200			Surface discharge	02/06/49
(Orange and Rockland	fuel	West bank	2	20	25,200	13.2	14.7	common to Units 1-3	07/12/51
Utilities, Inc.)			3	68	42,000				03/01/55
			4	187	104,000	17.0	21.3	Submerged near-surface	05/15/66
			5	202	120,000	14.0	20.2	Submerged near-surface	04/27/69
			Total	496	316,000	NA	57.0(i)		
Bowline Point	Fossil	37.5	1	622	384,000(e)	ΔT=14.9	62.0	Submerged diffuser	09/08/72
(Orange and Rockland	fuel	West bank	2	622	384,000(e)	ΔT=14.9	62.0	Submerged diffuser	05/13/74
Utilities, Inc.)(j)			Total	1,244	768,000(e)	NA	124.0		
59th Street	Fossil	5.0	Total of	132	168,000	6.7(k)	8.3(k)	Surface discharge	1918
(Consolidated Edison	fuel	East bank	7 units						
Company of New York,									
Inc.)									

(a) Adapted from McFadden 1977 (p. 27.1).
(b) Based on rating as of 24 April 1977.
(c) Roseton power plant is also partially owned by Con Edison and Niagara Mohawk.
(d) Indian Point Unit 1 requires both fossil and nuclear fuels.
(e) Including service water.

Note: NA indicates not applicable

(f) Indian Point Unit 1 was taken out of commercial operation on 31 October, 1974.
(g) Indian Point Unit 3 did not begin full load commercial operation until June 1974.
(h) On 30 December 1975 ownership of Indian Point Unit 3 was transferred from Con Edison to the Power Authority of the State of New York (PASNY).
(i) Including waste heat in service water (7,000 gpm).
(j) Bowline Point power plant is also partially owned by Con Edison.
(k) Some units at 59th Street supply steam to Manhattan. According to this supply, the heat load and plant temperature rise may vary.

els--including phytoplankton, macrophytes, zooplankton, benthos, and fish life stages--have been conducted since 1970, thus providing, to date, a data base that consists of 2.5 years of preoperational data, 1.5 years of data collected during single-unit operation and 4 years of two-unit postoperational data. Near-field effects of the Bowline Point plant can be evaluated from such data on the basis of pre- and post-operational comparisons; the availability of concurrent near-field and long-river survey data also permits an assessment of possible plant effects through comparisons of the biota within and outside the area of the river directly influenced by the plant.

Near-plant studies supported by the Hudson River utilities, have also been directed toward examining the impact of specific plant operational effects. These studies have included the collection and evaluation of data pertaining to the impingement (entrapment) of organisms on power plant intake screens, entrainment (i.e., passage of organisms through plant condenser cooling systems), hydrothermal analyses of plant discharge plumes, and laboratory experiments designed to assess the effects of exposure of organisms to elevated temperatures caused by plant cooling water discharges. As a result of these studies, the number and survival rates of organisms impinged and entrained has been determined for various plants. Additionally, the characteristics of plant thermal plumes have been defined in light of specific state thermal criteria, and thermal effects data for representative important species (RIS) have been obtained that can be used to predict the results of exposure of various life stages of these species to elevated plume temperatures.

The above studies have resulted in several reports which have been referred to in preparation of this document. Principal among these are the following:

1. "Bowline Point Generating Station Near-Field Effects of Once-Through Cooling System Operation on Hudson River Biota," referred to as ORU (1977) or Exhibit 7 in the 316(b) proceeding.

2. "Influence of Indian Point Unit 2 and Other Steam Electric Generating Plants on the Hudson River Estuary, With Emphasis on Striped Bass and Other Fish Populations," submitted originally by Con Edison to the Nuclear Regulatory Commission (NRC) in February 1977; referred to as McFadden (1977) or Exhibit 4 in the 316(b) proceeding.

3. Supplement I to the above report, referred to as McFadden and Lawler (1977) or Exhibit 3 in the 316(b) proceeding.

4. "Survival of Entrained Ichthyoplankton and Macroinvertebrates at Hudson River Power Plants," referred to as EA (1977a) or Exhibit 11 in the 316(b) proceeding.

5. "The Effects of Intakes and Associated Cooling Water Systems on Phytoplankton and Aquatic Invertebrates of the Hudson River," referred to as EA (1977b) or Exhibit 13 in the 316(b) proceeding.

6. "Bowline Point Generating Station Hydrothermal Analysis," referred to as LMS (1978). This report details information on the temperature distribution in the Hudson River estuary as it is affected by the operation of the Bowline Point plant. Analyses presented are based upon field measurements, mathematical and hydraulic model studies conducted by Lawler, Matusky and Skelly Engineers, and are considered in relationship to New York State thermal criteria. Descriptions of the plant's effect on dissolved oxygen in the river and the effects of chlorination to reduce condenser biofouling are also given.

7. "Thermal Effects Literature Review for Hudson River Representative Important Species," referred to as EA (1978a). This report provides a current review of the existing thermal effects literature for Hudson River RIS. Thermal effects information based on research conducted on Hudson River fish and invertebrate species by New York University Medical Center from 1971 to 1975 and Texas Instruments from 1972 to 1974 is presented, as it applies to specific RIS. The results of thermal effects studies conducted on these same RIS originating from other aquatic systems and geographical areas are summarized.

8. "Hudson River Thermal Effects Studies for Representative Species, Final Report," referred to as EA (1978b). This report presents the results and conclusions of recent laboratory thermal effects studies performed on Hudson River fish and macroinvertebrates by Ecological Analysts during 1976 and 1977.

In addition, documents relating to the cost-benefit analysis of natural draft cooling towers at the Bowline Point plant and other Hudson River steam-electric generating stations are available for review in conjunction with this demonstration. These documents include:

1. "Bowline Point Generating Station: Engineering, Environmental (Non-Biological), and Economic Aspects of a Closed-Cycle Cooling System," Exhibit 23 in the 316(b) proceeding.
2. "Report on Cost-Benefit Analysis of Operation of Hudson River Steam-Electric Units with Once-Through and Closed-Cycle Cooling Systems," Exhibit 28 in the 316(b) proceeding.

1.4 INTERRELATIONSHIPS OF 316(a) and 316(b)

Section 316 of the Federal Water Pollution Control Act Ammendments (the Act) includes consideration of environmental effects caused by power plant cooling water intake structures (316[b]), in addition to effects caused by thermal discharges (316[a]). Insofar as 316(a) demonstrations are concerned, the 1 May 1977 draft of the EPA 316(a) Technical Guidance Manual (EPA 1977) clearly indicates that an evaluation of thermal discharge effects should take into account the effects of other relevant sources of stress acting upon the indigenous population. As stated on pages 38 and 74 of the guidance manual, respectively:

> The impact of additive or synergistic effects of heat combined with other existing thermal or other pollutants in the receiving waters should also be considered.
>
> * * *
>
> In order to determine the indigenous population which will be subject to a thermal discharge under an alternative 316(a) effluent limitation, it is necessary to account for all nonthermal impacts on the population such as industrial pollution, commercial fishing, and the entrapment and entrainment effects of any withdrawal of cooling water through intake structures under the alternative 316(a) effluent limitation.

Thus, the implication is that a 316(a) determination should not be made independent of an evaluation of 316(b) issues. The interdependence of 316(a) and 316(b) is further pointed out and supported in the EPA Administrator's decision involving the Seabrook Nuclear Power Plant* (page 13):

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* Matter of Public Service Company of New Hampshire, Case 76-7, 17 June 1977, modified 9 November 1977.

> ...the applicant must persuade the RA (Regional Administrator) that the incremental effects of the thermal discharge will not cause the aggregate of all relevant stresses (including entrainment and entrapment by the intake structure) to exceed the 316(a) threshold....When Congress has so clearly set the requirement that the discharge not interfere with a balanced, indigenous population, it would be wrong for the Agency to put blinders on and ignore the effect of the intake in determining whether the discharge would comply with that requirement.

The studies described in Subsection 1.3.4 provide information directed toward an evaluation of plant intake effects (i.e., entrainment and impingement), thermal discharge effects, and other relevant sources of stress. Specifically, as stated in ORU 1977 (p. 1.2-6):

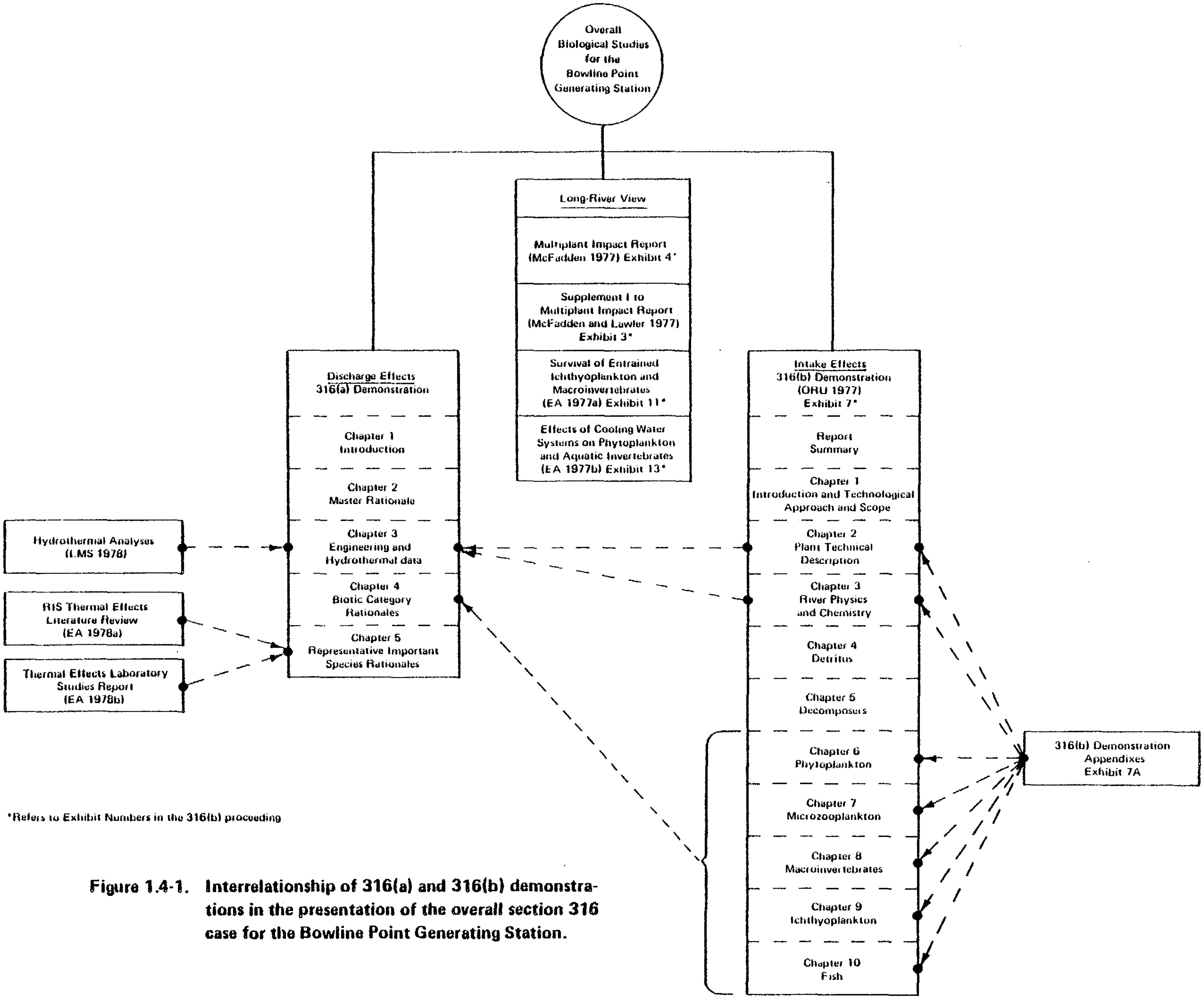
> ...much of the information reported here is applicable in evaluating thermal discharges. Actually, the analytical techniques used herein may not discriminate which of these factors (cropping or heat discharge) is actually causing any effect discerned to be of plant origin, so that any effect seen may be characterized as due to cropping, whereas in reality, it may be due to the heated water discharge.

In actuality, the analyses of general biological field-survey data, which are addressed in the 316(b) reports from the standpoint of pre- and post-operational and near-field versus far-field comparisons, examine the aggregate effects of the entire cooling water system. In other words, general field-survey data are useful in identifying possible effects on the biota that may be due to power plant operation, that is, changes in the biota which occurred after a power plant came online, or differences in the biota between that portion of the river in the immediate vicinity of the plant and similar river areas not directly influenced by the plant. However, such field data reflect the combined effect of all plant stresses and not the effects of individual stresses (i.e., entrainment, impingement, discharge heat, and chemical treatments).

Moreover, field survey data, as well as plant entrainment and impingement study data used in analyses presented in the Bowline Point plant 316(b) reports and related 316(b) long-river exhibits, were collected in the presence of all other sources of stress acting upon the ecosystem at the time. In this respect, the additive or possible synergistic effects of multiplant operation and other stresses are taken into consideration. Data collected after December 1974 were gathered, in fact, during a period when all power plants currently operating on the Hudson River estuary were online, with the exception of Indian Point Generating Station Unit 3 (see Subsection 1.3.4.1, Table 1.3-1). Therefore, estimates of the number and survival of organisms entrapped on or entrained through plant intake structures, as determined from plant intake or intake-discharge sampling, includes the influence of other stresses which may affect the susceptibility of organisms to intake mortality.

In like manner, postoperational data based on near-field biological surveys are influenced not only by the combined stresses of the power plant on the biota at the time of sampling, but by other "background" stresses acting upon that same community. Thus, if no differences in the near-field indigenous community are discernable from analyses of pre- and post-operational, and near-field versus far-field survey data, the implication is that the aggregate of all stresses associated with a given power plant, including possible interactions with other sources of stress existing within the waterbody, is not having a detectable or appreciable impact upon that community.

The interrelationships between this 316(a) demonstration, the Bowline Point plant 316(a) reports, and related exhibits and reference documents in providing total perspective to the overall Section 316 case is shown in Figure 1.4-1. Although, certain of the analyses presented in the 316(b) demonstra-



*Refers to Exhibit Numbers in the 316(b) proceeding

Figure 1.4-1. Interrelationship of 316(a) and 316(b) demonstrations in the presentation of the overall section 316 case for the Bowline Point Generating Station.

tion apply principally to intake effects, other analyses, as has been pointed out, apply more broadly to the effects of the discharge as well. These latter analyses provide valuable supportive information to the 316(a) case for the Bowline Point plant. In view of this, it will be noted that information presented in Chapter 4 (Biotic Category Rationales) of the present 316(a) demonstration has been synthesized largely from information presented in the biotic category chapters (i.e., Chapters 6-10) of the 316(b) demonstration.

In addition, this 316(a) demonstration provides evidence specific to an evaluation of thermal effects (Chapter 5) which has been drawn primarily from support documents that present the results of laboratory thermal effects studies on selected fish and aquatic invertebrates designated by EPA Region II as representative important species (RIS) for various Hudson River power plants. The 316(a) and 316(b) demonstrations both interrelate with the 316(b) long-river report exhibits (Figure 1.4-1) to portray the influence of the operation of the Bowline Point plant on the aquatic biota of the Hudson River estuary in relation to other power plant stresses which apply to this system.

REFERENCES: CHAPTER 1

Coutant, C. C. 1970. Biological aspects of thermal pollution. I. Entrainment and discharge canal effects. CRC Critical Reviews in Environmental Control 1(3):341-381.

Ecological Analysts, Inc. (EA). 1977a. Survival of entrained ichthyoplankton and macroinvertebrates at Hudson River power plants. Prepared for Central Hudson Gas & Electric Corporation, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. (EA). 1977b. The effects of intakes and associated cooling water systems on phytoplankton and aquatic invertebrates of the Hudson River. Prepared for Central Hudson Gas & Electric Corporation, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. (EA). 1978a. Thermal effects literature review for Hudson River representative important species. Prepared for Central Hudson Gas & Electric Corporation, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. (EA). 1978b. Hudson River thermal effect studies for representative species. Final report. Prepared for Central Hudson Gas & Electric Corporation, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers (LMS). 1978. Bowline Point Generating Station hydrothermal analysis. Prepared for Orange and Rockland Utilities, Inc.

McFadden, J. T. 1977. Influences of Indian Point Unit 2 and other steam electric generating plants on the Hudson River estuary, with emphasis on striped bass and other fish populations. Submitted to Consolidated Edison Company of New York, Inc.

McFadden, J. T. and J. P. Lawler. 1977. Supplement I to influence of Indian Point Unit 2 and other steam electric generating plants on the Hudson River estuary, with emphasis on striped bass and other fish populations. Submitted to Consolidated Edison Company of New York, Inc.

Orange and Rockland Utilities, Inc. (ORU). 1977. Bowline Point Generating Station near-field effects of once-through cooling system operation on Hudson River biota.

United States Environmental Protection Agency (EPA). 1974. 316(a) Technical Guide--Thermal Discharges, Draft. Water Planning Division, Office of Water and Hazardous Materials. Washington, D.C. 187 pp.

United States Environmental Protection Agency (EPA). 1977. Draft Interagency 316(a) Technical Guidance Manual and Guide for Thermal Effects Sections of Nuclear Facilities Environmental Impact Statements. Washington, D.C. 79 pp.

Chapter 2

MASTER RATIONALE

CHAPTER 2: MASTER RATIONALE

2.1 REQUEST FOR LESS STRINGENT EFFLUENT LIMITATIONS FOR THE BOWLINE POINT GENERATING STATION

Based on the evaluation criteria and information summarized below, it is demonstrated, in compliance with Section 316(a) of the Federal Water Pollution Control Act Amendments, that the thermal component of the cooling water discharge from the Bowline Point Generating Station, at present maximum net designed capability, will not interfere with the "...protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife..." in and on the Hudson River estuary. The absence of prior appreciable harm to the aquatic organisms in the vicinity of Bowline Point has been shown, and evidence presented which clearly indicates that the protection and propagation of RIS--and, therefore, other species at the site--will be assured. Consequently, the substantial costs required to install and operate a closed-cycle cooling system at the Bowline Point plant (capital costs of $77,820,000 and annual levelized operating and owning costs of $21,959,753) would be wholly disproportionate to the benefits to be achieved from the resulting insignificant reductions in the effects of the thermal discharge. On these grounds, Orange and Rockland Utilities, Inc. requests that the Bowline Point plant be granted less stringent effluent limitations that would allow continued use of the existing once-through cooling system with no restrictions on the discharge of heat.

2.2 SUMMARY OF EVIDENCE

The information presented in this document demonstrates that the cooling water discharge from the Bowline Point Generating Station assures the protection and propagation of the "balanced indigenous community" of the Hudson River estuary. No appreciable harm to the biological communities within this receiving waterbody has resulted from past operation of the Bowline Point plant, nor is any expected in the future. These conclusions result from a number of characterizations and analyses, considered individually and collectively. First, no appreciable harm would be expected based on (1) the natural characteristics of the biological community within the Hudson River estuary, and especially the distribution of its component organisms in time and space (2) the hydrothermal characteristics of the plant discharge, and (3) the experimentally determined organism responses to, and tolerance of, thermal exposure. Second, no appreciable harm from the Bowline Point discharge has in fact been observed during years of study based on (1) comparison of community structure and/or organism abundances during preoperational (1970-1972) and postoperational (1973-1976) years; or between near- and far-field areas, and (2) examination of the long-term historical composition of the Hudson River fish community. All of these areas of evidence are thoroughly described in Chapters 3, 4, and 5 and are interrelated in Chapters 4 and 5 to provide the rationales for concluding that no appreciable harm to major biotic categories or Representative Important Species (RIS) will occur as a result of the Bowline Point plant's thermal discharge. The following subsections summarize the main findings which support the conclusion that the "balanced indigenous community" of the Hudson River will be protected.

2.2.1 Characteristics of the Hudson River Biological Community

The dynamic nature of the Hudson River biological community is, in itself, an important factor contributing to the absence of appreciable harm. Spatial and temporal trends in the distribution, abundance, and species composition of the various aquatic community components within the Hudson River estuary are associated with natural environmental factors, such as temperature and salinity. The variation in salinity along the length of the estuary produces several different physicochemical enviroments and results in a changing community composition. The upper portion of the estuary (above MP 70) generally remains salt-free throughout the year and is, therefore, characterized by a freshwater assemblage of organisms. However, salinity in the lower portion of the estuary varies primarily as a function of freshwater flow, and the assemblage of organisms varies from one dominated by marine species to one comprised solely of freshwater forms, depending on time of year and longitudinal position in the estuary. The large seasonal variations in salinity in the middle portion of the estuary, including the Bowline Point vicinity, results in the presence of not one, but several "balanced indigenous communities" during various times of the year. However, normal seasonal trends in salinity and other environmental factors (e.g., temperature) results in some consistency (and therefore predictability) in the seasonal community structure at Bowline Point. Species composition and relative abundance of various biotic categories within the Hudson River estuary are extensively discussed in ORU (1977 Chapters 4-10), McFadden (1977:Subsection 2.2.9; Sections 3.8, 4.2, and 5.6), and are summarized in Chapter 4 of this demonstration.

The naturally occurring seasonal shifts in species assemblages in the estuary reduces the potential for appreciable harm from operation of the Bowline Point plant, since no single assemblage is exposed continuously to plant influence. Furthermore, the "balanced indigenous community" of the Hudson River is clearly very resilient since the pattern of dominant species assemblages are normally maintained from year to year in spite of dynamic natural seasonal cycles.

The specific temporal and spatial distributions of RIS contribute to the absence of appreciable harm. For many species, the potential for interaction with the thermal discharge from the plant is restricted in time, or completely eliminated by life history considerations. The primary spawning grounds of most important resident and anadromous fishes occur upstream or downstream from the Bowline Point plant, and as a result, depending on species, the potential for impact on spawning adults, eggs, and larvae is reduced or eliminated. Some species of fish prefer the deeper offshore zones of the estuary (e.g., shortnose sturgeon, Atlantic tomcod) and their involvement with the Bowline Point plume, which is predominantly surface oriented, is therefore negligible. Others do occupy shallow, shoal areas on a seasonal basis, but migrate during the late fall into deeper waters or downstream into the lower estuary or coastal water, thereby minimizing the potential for cold shock in the event of a total plant shutdown in winter. In addition, the egg and larval stages of most species are normally not present in midsummer when plume temperatures are at their highest.

2.2.2 Hydrothermal Characteristics of the Bowline Point Discharge

The combination of an offshore location and high velocity diffuser design for the Bowline Point plant's cooling water discharge structure achieves plume temperature conditions with little, if any, potential for adverse effects on aquatic life. Because of high initial dilution rates, the plume temperatures drop rapidly to within 2.4-4.3 C (4.3-7.7 F) of ambient within 5-10 seconds of the discharge port. Consequently, by the time the plume floats to the surface 30-60 ft from the discharge ports, considerable temperature decay has already occurred.

Surveys of the plume under varying tidal phases and seasonal and plant operational conditions have shown that in most cases the warmer plume temperatures are confined to the immediate vicinity of the discharge. The maximum percentages of river cross-sectional area and surface width within the 2.2 C (4 F) isotherm, based on field thermal survey measurements, were 5.5 and 7.9 percent, respectively. Therefore, more than 90 percent of the river cross section and surface width remain available as safe zones of passage as defined by the New York State thermal criteria even during plant operation approaching maximum capacity. Near shore shoal areas are seldom exposed to plume temperatures more than 0.6-1.1 C (1-2 F), and then only intermittently depending on tidal stage.

In addition, the thermal discharge from the Bowline Point plant has little effect on the far-field thermal regime, i.e., river temperatures outside of the immediate area of the thermal plume. Based on mathematical model results under unlikely severe summer conditions, a river cross-sectional, tidal-average temperature rise at Bowline Point (MP 37.5) of 0.2 C (0.4 F) was predicted to occur as a result of full-capacity operation of Bowline Point Units 1-2 (Subsection 3.3.2). The cross-sectional, tidal-average temperature rise at Bowline Point predicted for the combined thermal discharge from Bowline Point Units 1-2 and four other generating stations located in the mid-Hudson area (Lovett Units 1-5, Indian Point Units 1-3, Roseton Units 1-2, and Danskammer Units 1-4), assuming full-capacity operation for all units, was 0.9 C

(1.6 F). These low-level temperature increases are not expected to be biologically significant.

2.2.3 Thermal Requirements for Representative Important Species

The responses and tolerances of RIS to thermal exposure have been extensively studied at laboratories on the Hudson River. The results indicate that the thermal exposures produced by the Bowline Point plant discharge will not result in adverse effects on aquatic life.

Studies on entrainment simulation, upper thermal tolerance, lower thermal tolerance, hatching success and growth, and thermal preference indicate that:

1. Juvenile and adult life stages of RIS are capable of tolerating the maximum plume temperatures (4.3 C [7.7 F] above ambient) to which they would normally be exposed at the Bowline Point plant.
2. The results of cold shock experiments indicate that all of the RIS are capable of tolerating temperature drops greater than that which would be sustained in the event of a plant shutdown.
3. The RIS susceptible to plume entrainment (fish eggs and larvae, adult invertebrate zooplankton) have shown considerable tolerance to heat shock and would be expected to survive the short-term exposures to maximum discharge temperatures.
4. Temperature ranges for normal hatching success and growth of all of the RIS which might be exposed to the Bowline Point plume will not be exceeded as a result of the plant's thermal discharge.

2.2.4 No Prior Appreciable Harm

The thermal discharge and other facets of the operation of the Bowline Point plant (e.g., entrainment, impingement, chlorine discharges) have caused no prior appreciable harm to the balanced indigenous community of the Hudson River estuary. This conclusion is based on the absence of significant change in community composition and abundance between near- and far-field areas, and pre- and post-operational years, as indicated by field survey data collected in the Bowline Point area between 1970 and 1976. In addition, the river-wide composition of major fish species has not changed dramatically between 1936 and recent years (Subsection 4.6.3.2).

The survey data from which these conclusions were drawn were collected in the presence of all sources of stress acting upon the ecosystem at the time. Consequently, the additive or possible synergistic effects of multi-plant operation or other stresses are taken into consideration. Field data collected after December 1974, in fact, were gathered during a period when all power plants currently operating on the Hudson River estuary were online, with the exception of Indian Point Generating Station Unit 3. Thus, it has been demonstrated that the aggregate of all stresses associated with the cooling water system of the Bowline Point plant (i.e., intake as well as discharge effects), and other sources of stress existing within the receiving water system, is not having an appreciable impact upon the near-field and far-field indigenous, biological communities.

2.2.5 Evaluation Criteria

This demonstration addresses the evaluation criteria upon which a 316(a) determination is based (Subsection 1.3.3) and provides sufficient evidence to show that:

1. The biological community of the Hudson River will not be appreciably harmed by the thermal discharge of the Bowline Point plant. Evidence which shows the lack of prior appreciable harm for all biotic categories and the lack of predicted appreciable harm for the RIS is summarized above (Subsections 2.2.1 - 2.2.4) and presented in detail in Chapters 4 and 5, respectively.
2. Temperature requirements for survival, growth, and reproduction of RIS occurring in the receiving waters will not be exceeded as a result of the thermal discharge from the Bowline Point plant. Hydrothermal, life history, and thermal effects information, summarized in Subsections 2.2.1 - 2.2.3, is considered collectively in Chapter 5 and shows that temperature requirements of RIS likely to encounter the plume will be met by the design of the Bowline Point plant discharge.
3. No significant change in community structure resulting in increased abundance of organisms which might be considered a nuisance has been caused by the Bowline Point thermal discharge. Evidence presented in the biotic category rationales (Chapter 4) indicates that no trends in the abundance of blue-green algae has occurred beyond normal year-to-year variability.
4. Evidence presented in Chapter 3 and summarized in Subsection 2.2.2 demonstrates that a safe zone of passage (as defined by the New York State thermal criteria) equal to more than 90 percent of the river

cross-sectional area at Bowline Point will be assured. Chapter 4 presents evidence that no prior appreciable harm (see Subsection 2.2.4) has occurred to the RIS, implying that normal spawning migrations and movements of the organisms have not been blocked or interrupted.

5. The only threatened or endangered species present in the vicinity of the Bowline Point plant is the shortnose sturgeon (*Acipenser brevirostrum*). The life history of this species has been reviewed in Subsection 5.3.4.7. Although no thermal effects data are available, the distribution of this species, as indicated in Subsection 2.2.1, makes involvement with the thermal discharge of the Bowline Point plant unlikely.
6. There will be no destruction of rare or unique habitat. There are no rare or unique habitats within the influence of thermal plume created by the Bowline Point plant's cooling water discharge. Marshland present in the area is contacted only intermittently by plume temperatures less than 0.6-1.1 C (1-2 F) above ambient. Thus, no destruction of such habitat will occur.
7. The planned use of biocides, such as chlorine, will not result in appreciable harm to the balanced indigenous community. Due to the low levels of organic growth in the condensers which have occurred in the past, cooling water at each unit of the Bowline Point plant is chlorinated separately for 30 minutes, three times a week, only during periods when river temperatures exceed 10 C (50 F). Based on this frequency, approximately 115 lb. per week of free residual chlorine are discharged into the river during the chlorination period to achieve an average free residual chlorine concentration of 0.2 mg/liter

at the outlet of the condenser. Recent studies reported in the literature (Subsection 3.3.3.2) indicate that the low-level residual chlorine concentrations in the receiving water at Bowline Point, resulting from intermittent chlorination to control biofouling, are well within expected safe levels for aquatic organisms and will not have any appreciable effect on the biota of the Hudson River estuary.

Chapter 3
ENGINEERING AND HYDROTHERMAL DATA

CHAPTER 3: ENGINEERING AND HYDROTHERMAL DATA

This chapter describes the principal physicochemical characteristics of the receiving water system in the vicinity of the Bowline Point Generating Station (Section 3.1), engineering data relating to the design and operation of the plant's cooling water system (Section 3.2), and the effects of the cooling water discharge upon the temperature, hydrology, and water chemistry of the receiving water (Section 3.3). Certain of the results derived in the hydrothermal analyses of the discharge that have important implications with respect to the interpretation of biological data, or the prediction of biological effects, are summarized in Section 3.4.

The material presented herein has been selected on the basis of its relevancy to a 316(a) demonstration and is the primary information considered in evaluating the effects of the plant's thermal discharge on the biota of the lower Hudson River estuary (Chapters 4 and 5). Certain portions of this chapter have been drawn in whole or in part from the report entitled "Bowline Point Generating Station Hydrothermal Analysis" (LMS 1978), which presents more detailed information on the effects of the Bowline Point plant's cooling water discharge on the temperature distribution in the Hudson River estuary. Additional descriptions of engineering and operational features of the Bowline Point plant are presented in ORU (1977:Chapter 2), and comprehensive information on the physical, chemical, and hydrological characteristics of the Hudson River estuary may be found in Texas Instruments (1976), McFadden (1977:Chapter 2), and ORU (1977:Chapter 3).

3.1 PLANT LOCATION AND CHARACTERISTICS OF THE RECEIVING WATER*

3.1.1 Plant Locale and River Morphometry

The Bowline Point plant is located on the west bank of the Hudson River estuary (at milepoint [MP] 37.5) in the Town and Village of Haverstraw, New York. The river in the vicinity of Bowline Point is relatively shallow and wide (Figures 3.1-1 and 3.1-2); in fact, the river reaches its widest expanse in this area (i.e., approximately 18,000 ft, or 3.4 mi). Mean depth in the river cross section at Bowline Point is about 18 ft at mean low water (MLW), and the greatest depth in the area (31 ft MLW) occurs within the shipping channel located near the west shore. The area of the river east of the shipping channel to the east shoreline is characterized by the extensive shallow areas of Haverstraw Bay.

The river narrows and deepens north of Bowline Point; 3 mi upstream near Verplank, the river is approximately 3,500 ft wide and up to 70 ft (MLW) deep. South of Bowline Point the river remains wide and shallow until south of Piermont Pier (MP 25) where the cross section again becomes narrow and deep (Figure 3.1-2). However, just below Croton Point, 3.2 mi south of Bowline Point, the deeper channel waters switch from the west to the east shore, and from this point downstream to Piermont Pier the extensive shallow areas of Tappan Zee are found on the west shore.

The river bottom substrate in the vicinity of Bowline Point, as determined during both low and high flow periods, is predominantly silt.

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* Material in this section, unless otherwise referenced, is summarized from Orange and Rockland Utilities, Inc. (1977:Chapter 3, River Physics and Chemistry).

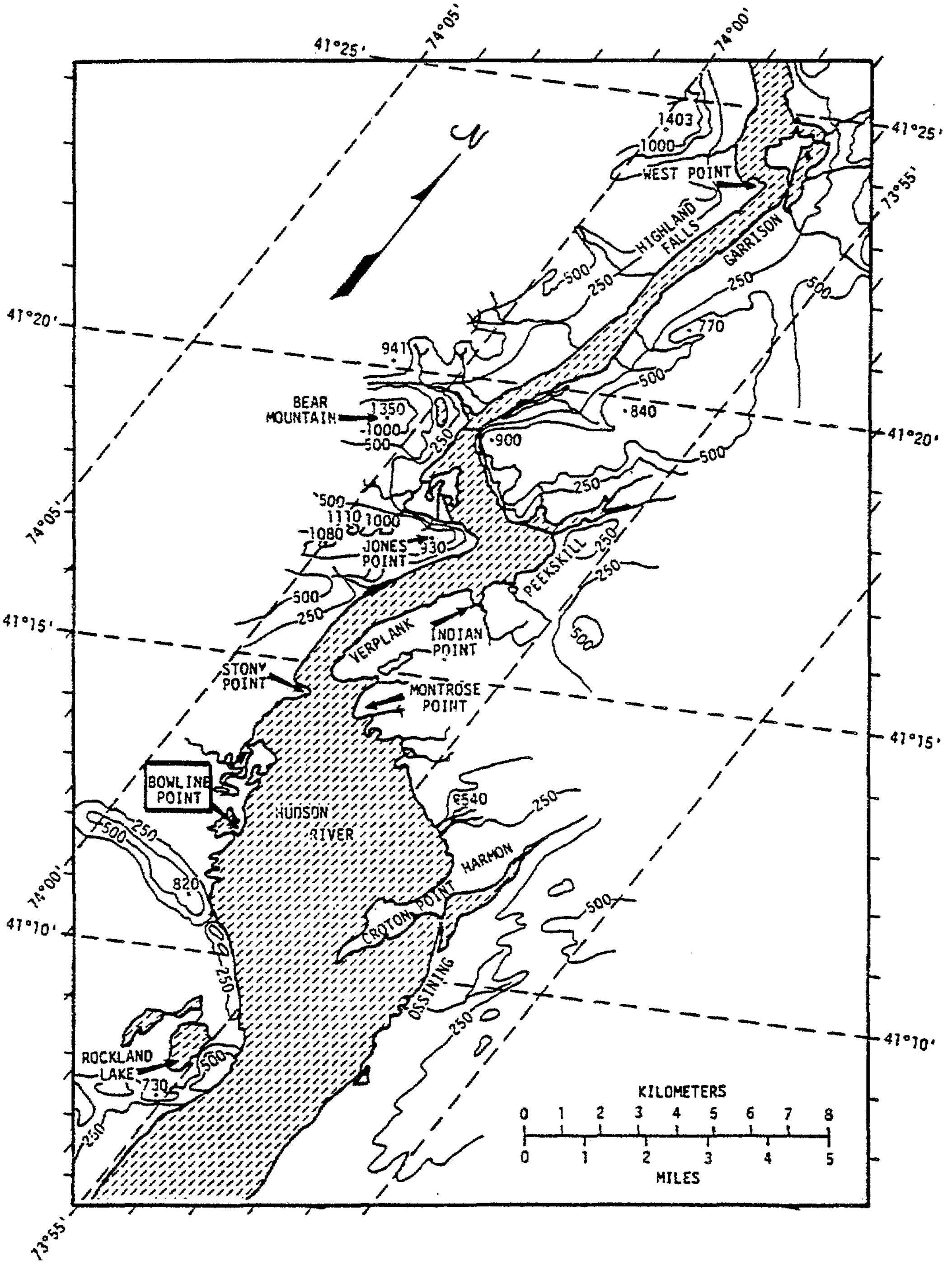
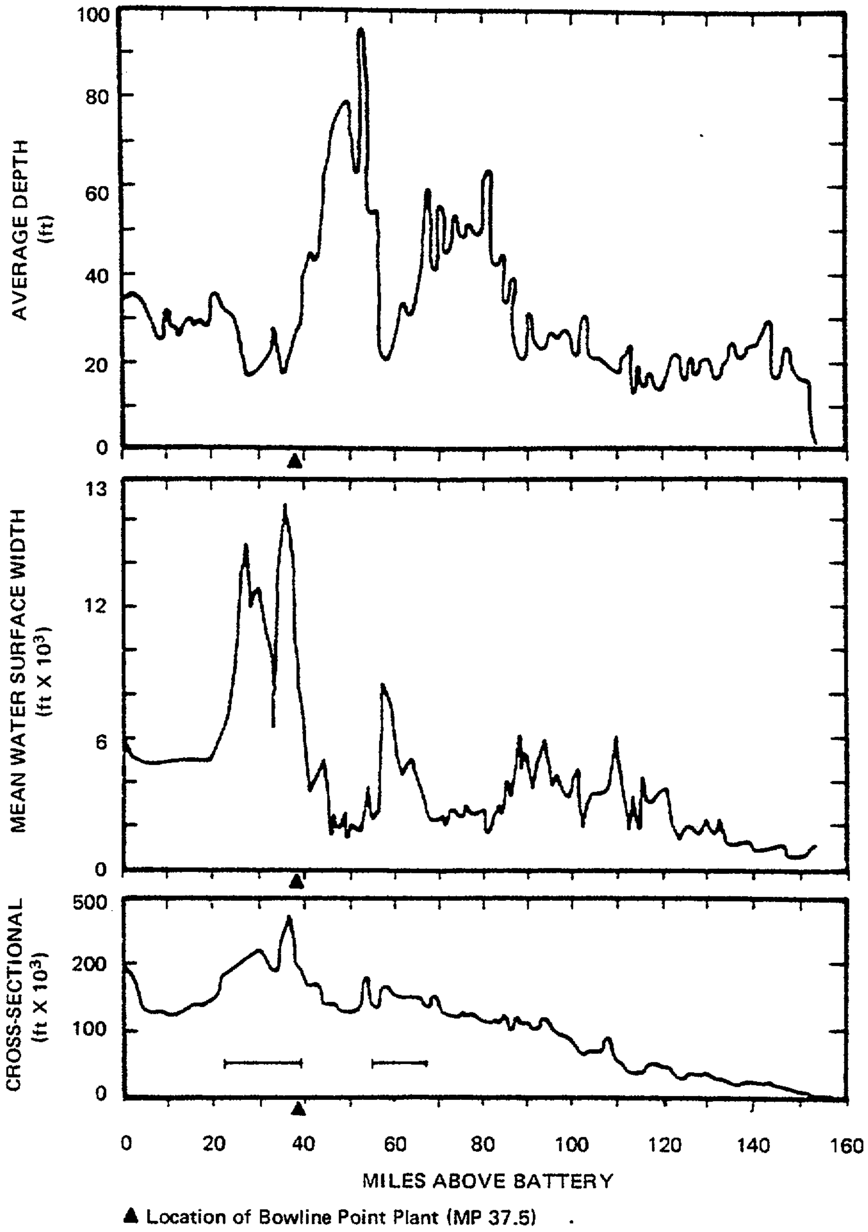
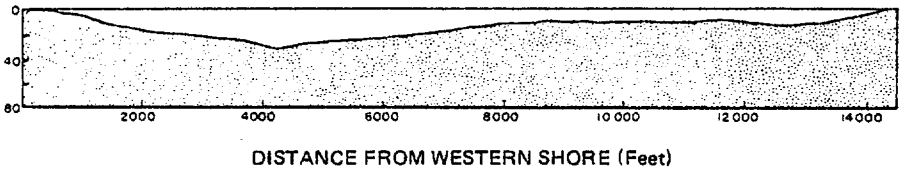


Figure 3.1-1. Hudson River estuary in the vicinity of the Bowline Point Generating Station (adapted from McFadden 1977:p. 2.6).



(a) Channel physical characteristics



(b) Channel cross section at the Bowline Point plant discharge

Figure 3.1-2. Physical characteristics of the Hudson River channel in the vicinity of the Bowline Point Generating Station (adapted from McFadden 1977:pp. 2.22 and 2.108).

3.1.2 River Hydrology

3.1.2.1 Freshwater Flow

Freshwater inflow into the Hudson River estuary provides a net downstream movement of water in the estuary. Freshwater flow within the estuary is quantitatively determined primarily from flow entering the lower river at the Troy Dam (MP 152), as measured at the USGS gaging station at Green Island. Because there are no gaging stations south of Green Island, the freshwater flow of the estuary is taken as the flow measured at Green Island and corrected to account for tributaries that enter the estuary between Green Island and Wappinger Creek (MP 67). The freshwater flow cycle follows a typical seasonal runoff pattern, with maximum flows occurring predominantly during the spring months (March, April, and May) and the period of low freshwater flows usually beginning in June and continuing until November; regulated releases from Sacandaga Reservoir are used to maintain the freshwater flow at Green Island at 3,000 cfs even during drought conditions. The long-term (1918-1975) annual freshwater flow at Green Island is 13,268 cfs corresponding to a freshwater flow in the estuary downstream of Wappinger Creek of 19,010 cfs.

During the 1960s, the entire northeastern region of the United States experienced a severe drought period characterized by extremely low freshwater flows. The most severe drought in the Hudson River was observed during June-November 1964. Throughout this period, mean monthly flows in the Hudson River varied within a small range and averaged approximately 3,500 cfs.

Record floods within the Hudson River have occurred infrequently. Peak flows at Green Island during the last significant floods were: 215,000 cfs in 1936; 183,000 cfs in 1938; 181,000 cfs in 1948; and 135,000 cfs in 1960. However, such flood flows are of importance only in the uppermost portions of the estuary. Flood waves enter the relatively small channel below the Troy Dam and "push" the tide back downstream. Within a few miles downstream, the opposing forces of the flood and tide waves result in a damping effect on the flood wave and a flattening of the slope of the flood profile. Throughout the remainder of the estuary, tide and wind effects are the predominant causes of high water levels (Darmer 1969:pp. 40-45).

In recent years (1971-1976), the Hudson River has experienced a wet period during which monthly average freshwater flows have generally been higher than their long-term counterparts (Table 3.1-1). Seasonal patterns during these years have been characterized by mild wet winters with average flows, normal to slightly above average flows in the spring, and wet summers and autumns with above average flows.

3.1.2.2 Tidal Flow

The entire Hudson River estuary from New York Harbor to the Troy Dam (MP 152) is subject to tidal influence. However, moving upstream the mean tidal amplitude diminishes from about 4.4 ft at the Battery in New York City to a minimum of about 2.6 ft near Storm King Mountain (MP 56) and then increases again to its maximum of 4.7 ft at Troy. This condition results from a reflection of the tidal wave at the upstream end of a narrow, deep portion of the river channel. The same longitudinal pattern exists for amplitude extremes, mean tide level, and mean high water level (Figure 3.1-3). The mean tidal flow also varies along the estuary, decreasing from a maximum of 425,000 cfs at the Battery to zero at the Troy Dam. Near Bowline Point the average tidal flow is about 150,000 cfs; the average ebb current velocity is 1.44 fps, and the average flood current velocity is 0.96 fps (LMS 1978:p. 3-2). Mean tidal flow

TABLE 3.1-1 MONTHLY AVERAGE FRESHWATER FLOWS (cfs) FOR THE HUDSON RIVER ESTUARY*

Month	1918-1975 Long-Term Average Flows(a)	1971	1972	1973	1974	1975	1976(b)
JAN	12,833	9,002	13,410	26,210	22,010	19,070	14,772
FEB	12,199	12,110	10,930	20,460	18,640	19,370	31,105(c)
MAR	22,190	20,220	26,260	29,410	20,730	23,680	31,601
APR	31,060	37,270	37,960	30,960	30,170	25,580	36,727
MAY	19,028	35,240	40,520(d)	27,600	22,960	20,000	31,781
JUN	9,684	7,334	29,630(c)	13,050	8,791	12,970	15,209
JUL	6,900	6,233	18,380(d)	10,390	11,780	7,464	15,237
AUG	5,446	8,929	7,616	5,591	6,359	8,966	14,589(c)
SEP	6,231	9,315	6,309	4,791	10,390	17,030(d)	9,534
OCT	7,772	7,811	7,291	5,650	9,049	23,360(d)	23,002
NOV	12,200	7,291	26,150(d)	8,280	17,180	22,420	17,692
DEC	13,771	17,000	27,010(d)	26,420	19,380	18,647	13,918
MEAN	13,268	14,830	20,956	19,278	16,715	18,116	21,233

(a) Based on freshwater flows recorded at the USGS gaging station at Green Island from 1947 to 1975, and on flows recorded for the upper Hudson River at Mechanicsville and Mohawk River at Cohoes from 1918 to 1946.

(b) Preliminary data.

(c) Highest recorded monthly average flow since 1918.

(d) Second highest monthly average flow since 1918.

*Note: Adapted from ORU 1977:Table 3.1-2.

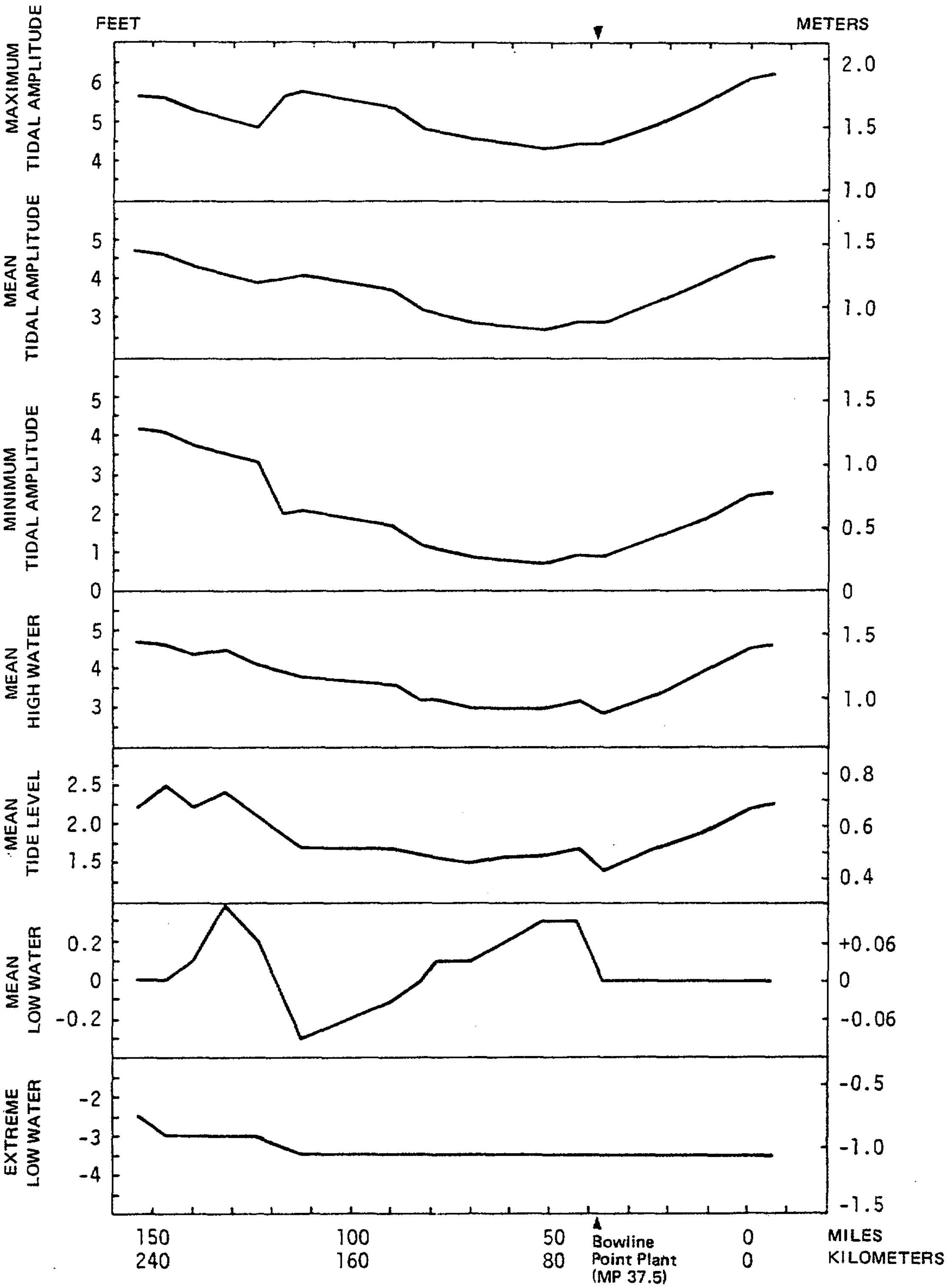


Figure 3.1-3. Longitudinal changes in major indices of tidal activity (data courtesy USCGS hydrographic charts).

values are affected by freshwater flow, particularly in the upstream reaches of the estuary. High freshwater flows generally decrease tidal velocities and flows during flood tides and increase tidal velocities and flows during ebb tides.

3.1.2.3 Density-Induced Circulation

Partially stratified estuaries such as the Hudson River estuary are subject to a net upstream movement in the lower water layers and a net downstream movement in the upper water layers. Owing to tidal motion, turbulent eddies mix the lighter freshwater downwards and the heavier saltwater upwards, causing an increase in the potential energy of the water. This action tends to dilute the landward-flowing saltwater and increase the density of the seaward-flowing freshwater. As a result, the volume of the seaward-flowing layer increases. To compensate for this increase, more ocean-derived water intrudes upstream in the lower layer. Thus, a circulation pattern is developed in which the water moves downstream in the upper layer and upstream in the lower layer. This circulation pattern, which results from density differences caused by the vertical and longitudinal distribution of ocean-derived saline water, is referred to as density-induced circulation, or net nontidal flow. The kinetic energy required for this circulation is provided by the increase in the potential energy of the water caused by vertical mixing.

Density-induced circulation is important because it provides additional water for the dilution of discharges and affects the distribution of biological organisms such as fish eggs and larvae. Dilution flows resulting from such circulation may be many times higher than those caused by upstream runoff; in several estuaries, dilution flows of from 10 to 40 times the associated freshwater flows have been observed. However, the density-induced circulation pattern is weakest where salt is not present. The Bowline Point plant is located within the salt-intruded reach of the Hudson River estuary when the freshwater flow is below 26,000 cfs. This flow (i.e., 26,000 cfs), therefore, represents a conservative estimate of river dilution flow in the area of the plant, and at a plant cooling water flow of 1,163 cfs corresponds to a minimum dilution ratio (plant flow/dilution flow) of 1:22.4. Based on the long-term average freshwater flow in the Hudson River estuary (approximately 10,000 cfs), the computed long-term average dilution flow at Bowline Point is about 30,000 cfs, which represents a dilution ratio of 1:25.8.

3.1.3 Water Quality

3.1.3.1 Salinity and Stratification

The Bowline Point area of the Hudson River estuary (MP 37.5) is normally located south of the northern boundary (MP 50-70) of saltwater intrusion from the ocean. When the freshwater flow is high, the salt front (defined as that location where the tidally averaged concentration of salinity is 100 mg/liter) moves south of the Bowline Point area, but during low-flow periods the salt front moves further north.

Calculation of the tidally averaged salt intrusion length as a function of steady-state freshwater flow conditions of the Hudson River estuary indicates that the Bowline Point area is within the salt-intruded reach of the estuary when the freshwater flow is less than about 26,000 cfs. Based on monthly average freshwater flows from 1918 to 1975, the salt front is generally located north of the Bowline Point area during all months of the year except the high flow months of March, April, and possibly May, which is a borderline flow case (i.e., average freshwater flow during May is approximately 26,000 cfs). However, these estimates represent a long-term average, and the length of occurrence of the salt front in the vicinity of Bowline Point may be different for any given year. For example, during the drought year of 1965, the salt front was in the Bowline Point area for the entire year, whereas during the high flow years of the early 1970s the salt front was present in this area only 4-5 months annually. Although the salt front is usually located in the Bowline Point area or further north during most of the year, the mean salinity concentration varies according to the extent of salt intrusion. Salinity concentrations in the vicinity of Bowline Point have ranged from as high as 8,500 mg/liter during drought conditions, to as low as 30-50 mg/liter (background salinities) during periods of high freshwater flow.

Over the recent period from 1973 to 1976, freshwater flows, fed by heavy rainfall and runoff, have been higher than normal. As a result, average chloride concentrations in the vicinity of Bowline Point have ranged from generally less than 3,000 mg/liter to as low as 10 mg/liter (background concentration) for freshwater flows in excess of 30,000 cfs. The river now appears to be in a high flow cycle which results in low salinities in the Bowline Point area.

Because the Bowline Point area is located in varying positions with respect to the salt front, this results in variation in the extent of vertical stratification. Vertical stratification occurs in the Hudson River at Bowline Point whenever the salt front is north of this area and is caused by the heavier seawater intruding upstream beneath the lighter freshwater. More pronounced stratification occurs when the mean concentrations of chlorides are greater than 1,000 mg/liter; at these levels the bottom and surface concentrations can differ by a ratio of as much as 15:2.

3.1.3.2 Temperature Regime

Within the Hudson River estuary, as within any given natural water system, ambient water temperatures vary both temporally (seasonally and daily) and spatially (over the length, width, and depth of the waterbody). Such changes are natural phenomena caused by waterbody geometry, terrestrial runoff, dispersion and circulation, temperatures of the ocean and freshwater, and climatological conditions such as air temperature, wind, and solar radiation.

The two background temperatures (i.e., those of the ocean water and freshwater entering the estuary) follow the same general seasonal pattern although there is a time lag because warming and cooling processes take place in ocean water after they have already occurred in freshwater (McFadden 1977:pp. 2.43-2.44). This phenomenon occurs because relatively shallow streams discharging freshwater into the estuary warm and cool more rapidly than ocean water, which never reaches the seasonal temperature extremes of streams and rivers. Since the effect of freshwater temperature is more pronounced in the upper reaches of the estuary and that of ocean water temperature predominates in the downstream portions of the estuary, longitudinal temperature gradients often occur. The ocean water entering the mouth of the estuary is generally warmer during the winter and cooler during the summer than freshwater entering the head of the estuary at Green Island (Figure 3.1-4).

In the Hudson River estuary as a whole, water temperatures are generally highest during July and August, and lowest during January and February. However, considerable variation occurs from year to year. For example, water temperature measurements recorded from 1951 to 1976 by the City of Poughkeepsie De-

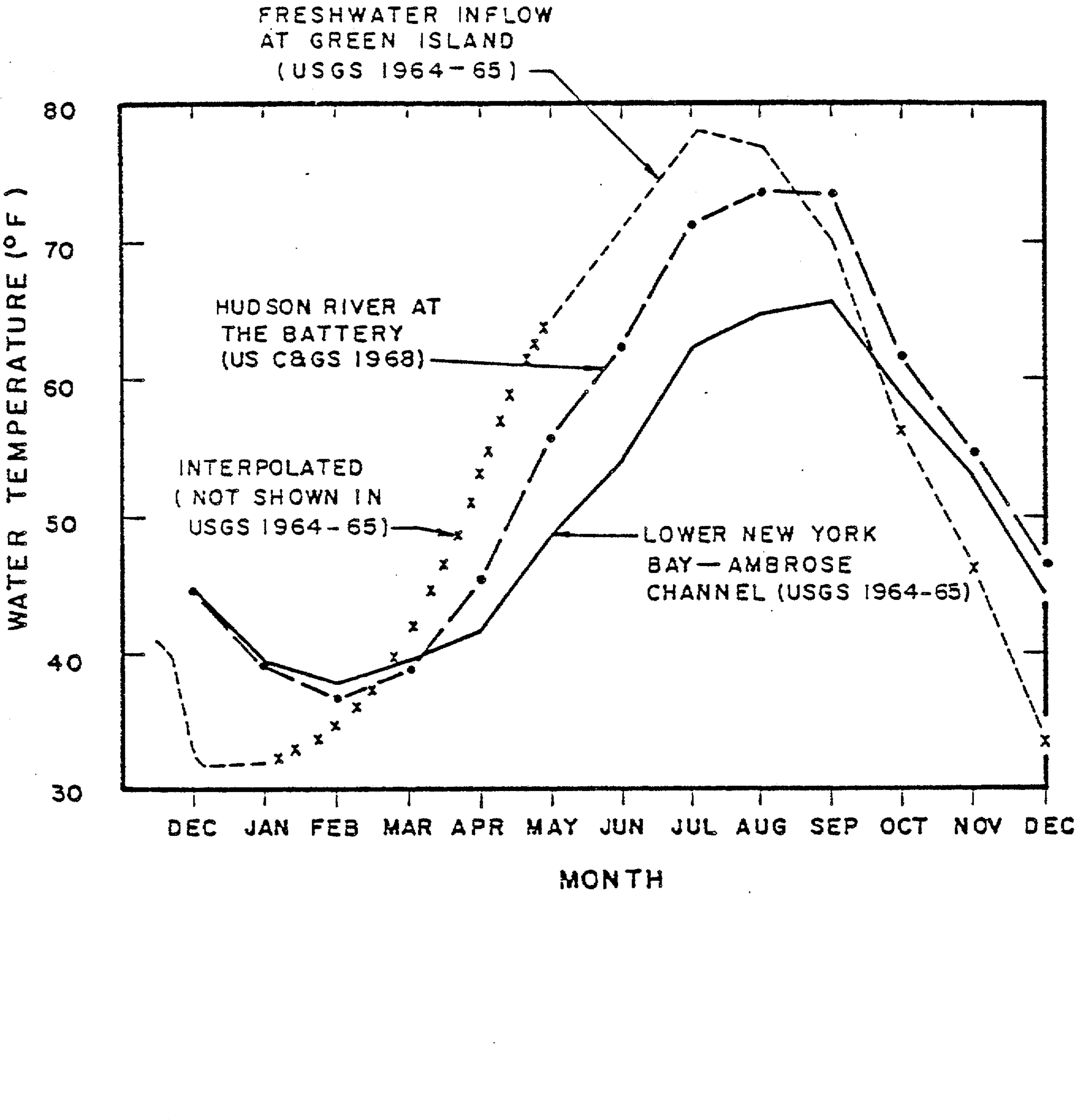


Figure 3.1-4. Comparisons of seasonal variations in temperatures of marine and freshwaters entering the Hudson River estuary, 1964 (from McFadden 1977:p. 2.44).

partment of Public Works at Poughkeepsie, New York* (MP 75)--the approximate midpoint of the estuary--indicate that river temperatures were $\geq$25.0 C (77 F) on all days of August during 1959 and 1970, but during no days in August of 1954, 1960-1962, and 1976 (Table 3.1-2). Annual maximum temperatures over this 26-year period varied 3.9 C (7 F), i.e., from 23.3 to 27.2 C (74 to 81 F). Similarly, during many winters throughout these 26 years, the river temperature was never $\leq$0.6 C (33 F) in February, whereas during others the February temperature was less than or equal to this value during all days (Table 3.1-3).

In addition to seasonal temperature variation, McFadden (1977:p. 2.47)--based on 1974-1975 water temperature data for the Hudson River estuary--noted diurnal, vertical, and latitudinal (river width) temperature differences of up to 2.2 C (4 F) throughout the year, and longitudinal variation within the estuary of up to 8.2 C (15 F). McFadden (1977:pp. 2.44, 2.47-2.49) also pointed out that similar variations in temperatures of the estuary occurred prior to the existence of any significant artificial heat source. Specifically, water temperatures recorded during August and September 1929 (as part of a USGS current survey of the Hudson River) indicated the following: diurnal changes in river temperatures by 1.6 C (3 F) within approximately an 8-hour period; vertical variation of 0.8 C (1.4 F) over depths of 20 ft; latitudinal differences of 1.6 C (3 F) across the river width; and longitudinal temperature variation of approximately 5.0 C (9 F) over the length of the estuary.

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* Because Poughkeepsie is located 67 mi south of the Albany plant and approximately 9 mi north of the Danskammer Point and Roseton plants (and on the opposite side of the river; see Section 1.1, Figure 1.1), this site is expected to be generally outside of the influence of residual (far-field) heat from power plant thermal discharges. Therefore, temperatures recorded at this site are considered indicative of the background ambient river temperatures in the freshwater portion of the estuary.

TABLE 3.1-2 VARIATIONS IN WATER TEMPERATURES OF THE HUDSON RIVER ESTUARY AT POUGHKEEPSIE (MP 75) DURING JULY AND AUGUST 1951-1976[(a)]

Year	Maximum Observed Temperature During Year in Degrees F(C)	Percent of Days with Temperature Equal to or Greater than Stated Value					
		JUL			AUG		
		77 F (25.0 C)	75 F (23.9 C)	73 F (22.8 C)	77 F (25.0 C)	75 F (23.9 C)	73 F (22.8 C)
1951	77 (25.0)	3	68	97	6	97	100
1952	79 (26.1)	42	71	90	71	100	100
1953	78 (25.6)	55	84	90	29	58	100
1954	76 (24.4)	0	19	96	0	62	96
1955	79 (26.1)	50	92	100	67	100	100
1956	76 (24.4)	0	0	64	0	52	100
1957	78 (25.6)	63	100	100	27	63	89
1958	78 (25.6)	0	41	59	73	92	100
1959	80 (26.7)	8	54	58	100	100	100
1960	74 (23.3)	0	0	50	0	0	63
1961	75 (23.9)	0	23	42	0	39	100
1962	75 (23.9)	0	56	100	0	0	86
1963	78 (25.6)	15	41	100	48	78	100
1964	78 (25.6)	41	89	100	88	100	100
1965	77 (25.0)	0	59	89	8	100	100
1966	80 (26.7)	92	100	100	96	100	100
1967	79 (26.1)	52	72	100	89	100	100
1968	78 (25.6)	42	46	62	89	100	100
1969	78 (25.6)	0	96	100	56	100	100
1970	80 (26.7)	11	41	85	100	100	100
1971	78 (25.6)	67	100	100	92	92	100

(a) Based on daily observations by the City of Poughkeepsie Department of Public Works. The number of days during which water temperature measurements were recorded ranged from 25 to 31 days for both July and August, since during some years measurements were not taken during weekends or holidays. The percentage of days during the month with temperature equal to or greater than the stated value is based only upon those days for which records exist.

TABLE 3.1-2 (CONT.)

		Percent of Days with Temperature Equal to or Greater than Stated Value					
		JUL			AUG		
Year	Maximum Observed Temperature During Year in Degrees F(C)	77 F (25.0 C)	75 F (23.9 C)	73 F (22.8 C)	77 F (25.0 C)	75 F (23.9 C)	73 F (22.8 C)
1972	79 (26.1)	27	38	50	30	78	100
1973	78 (25.6)	15	77	77	56	100	100
1974	77 (25.0)	0	26	63	26	100	100
1975	81 (27.2)	67	81	100	37	100	100
1976	77 (25.0)	22	100	100	0	27	100
Long-Term Avg.	78 (25.6)	26	61	84	46	78	97

(a) Based on daily observations by the City of Poughkeepsie Department of Public Works. The number of days during which water temperature measurements were recorded ranged from 25 to 31 days for both July and August, since during some years measurements were not taken during weekends or holidays. The percentage of days during the month with temperature equal to or greater than the stated value is based only upon those days for which records exist.

TABLE 3.1-3 VARIATIONS IN WATER TEMPERATURES OF THE HUDSON RIVER ESTUARY AT POUGHKEEPSIE (MP 75) DURING JANUARY AND FEBRUARY 1951-1976[(a)]

	Percent of Days with Temperature Equal to or Less than Stated Value					
	JAN			FEB		
Year	33 F (0.6 C)	34 F (1.1 C)	36 F (2.2 C)	33 F (0.6 C)	34 F (1.1 C)	36 F (2.2 C)
1951	23	90	100	0	82	100
1952	0	42	100	0	0	86
1953	3	61	100	0	61	96
1954	41	85	93	12	46	100
1955	54	100	100	25	33	83
1956	0	0	76	0	20	72
1957	31	85	100	0	29	92
1958	0	44	67	0	71	96
1959	8	71	100	8	67	96
1960	24	60	100	31	96	100
1961	9	30	65	54	100	100
1962	85	100	100	100	100	100
1963	100	100	100	100	100	100
1964	81	100	100	0	100	100

(a) Based on daily observations by the City of Poughkeepsie Department of Public Works. The number of days during which water temperature measurements were recorded ranged from 23 to 31 days (average--26 days) for January, and 18 to 29 days (average--24 days) for February, since during some years measurements were not taken during weekends or holidays. The percentage of days during the month with temperature equal to or less than the stated value is based only upon those days for which records exist.

TABLE 3.1-3 (CONT.)

Year	Percent of Days with Temperature Equal to or Less than Stated Value					
	JAN			FEB		
	33 F (0.6 C)	34 F (1.1 C)	36 F (2.2 C)	33 F (0.6 C)	34 F (1.1 C)	36 F (2.2 C)
1965	56	72	92	100	100	100
1966	0	52	100	0	100	100
1967	0	64	100	0	100	100
1968	0	85	100	0	56	100
1969	35	69	100	0	17	100
1970	19	100	100	0	92	100
1971	84	100	100	67	96	100
1972	38	92	100	92	100	100
1973	69	92	100	100	100	100
1974	54	85	100	67	92	100
1975	11	59	100	0	88	100
1976	100	100	100	35	74	91
Long-Term Avg.	36	75	96	30	74	97

Table 3.1-4 shows monthly average water temperatures and maximum annual water temperatures for the lower Hudson River estuary, at Peekskill, New York (MP 43), based on USGS measurements taken daily (or several times a day) from October 1959 to February 1969. As indicated by Con Edison (1977:p. 2-11), these temperatures may be slightly above true ambient conditions for this portion of the river, since they were taken in shallow waters of Lents Cove (1959-1966) and near the west bank of the river at Jones Point (1966-1969), sites that may be affected by increased heating from solar radiation and reduced mixing. However, these data represent the most extensive river temperature records available in the Bowline Point vicinity (both in terms of the total period covered and the frequency of measurements), and provide a conservatively warm base for predictively evaluating possible biological effects from the Bowline Point plant's thermal discharge (Chapter 5). Furthermore, these temperatures are relatively consistent with those measured at Poughkeepsie (Table 3.1-2).

In recent years (1973-1976), temperature data have also been recorded in the vicinity of Bowline Point during the near-field biological sampling program (Section 1.3.4). Table 3.1-5 presents monthly average water temperatures for this period based upon mean values for all depths (surface, middepth, and bottom) at river near-field biological stations. The frequency of these measurements was usually at least once a week during the early years of the program, increasing to two or three times a week more recently (LMS 1978:p. 4-3). Although temperatures were not generally taken directly in the thermal plume, they do reflect any residual, far-field heat from the Bowline Point plant or other generating stations that discharged into the river during this period.

A summary of the 10-year (1959-1969) mean monthly average water temperatures in the Bowline Point vicinity based upon USGS Peekskill records, and the mini-

TABLE 3.1-4 MONTHLY AVERAGE WATER TEMPERATURES FOR THE LOWER HUDSON RIVER ESTUARY IN THE VICINITY OF BOWLINE POINT, 1959-1969[a]

	Monthly Average Temperatures in Degrees C												Maximum Temperatures for Year	
Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	C	(F)
1959	--	--	--	--	--	--	--	--	--	19.4	10.6	3.3	(b)	(b)
1960	0.6	0.6	0.6	6.7	15.0	21.1	23.9	24.4	22.2	17.2	11.1	4.4	25.0	(77)
1961	0.0	0.0	1.7	6.7	13.3	19.4	23.9	25.0	25.0	18.9	12.8	5.6	26.7	(80)
1962	0.6	0.0	1.1	7.2	14.4	21.1	23.9	23.9	21.7	17.2	10.6	3.3	24.4	(76)
1963	0.6	0.6	1.1	7.2	13.3	19.4	24.4	25.0	21.0	16.7	12.8	5.6	26.1	(79)
1964	0.6	0.0	2.2	7.2	14.4	20.0	24.4	23.9	22.8	16.1	11.7	5.6	25.6	(78)
1965	1.7	0.0	1.7	6.1	14.4	20.6	23.3	24.4	22.8	16.7	10.6	5.0	25.6	(78)
1966	1.1	0.0	1.7	6.7	11.7	18.9	25.6	25.0	22.8	18.2	12.9	7.6	27.2	(81)
1967	4.3	2.8	3.0	7.7	13.0	20.3	24.9	26.2	(c)	19.2	10.7	3.9	27.2	(81)
1968	(c)	1.0	(c)	(c)	15.9	(c)	(c)	(c)	23.4	19.1	11.4	3.0	27.0	(80.6)
1969	0.6	1.1	--	--	--	--	--	--	--	--	--	--	(b)	(b)
10-yr avg														
C	1.1	0.6	1.6	6.9	13.9	20.1	24.3	24.7	22.7	17.9	11.5	4.7		
(F)	(34.0)	(33.1)	(34.9)	(44.4)	(57.0)	(68.2)	(75.7)	(76.5)	(72.9)	(64.2)	(52.7)	(40.5)		

(a) Based on USGS temperature records for Peekskill, New York. For the period October 1959 to September 1966, water temperature measurements were made once daily on the east side of the river at Charles Point (MP 43) on Lents Cove. During October 1966 through February 1969, temperatures were recorded several times a day at Jones Point on the west side of the river opposite Charles Point. Following February 1969, the Jones Point station was discontinued.

(b) Insufficient data.

(c) More than 33 percent of the days within the month were not sampled.

Note: Dash (--) indicates no data.

TABLE 3.1-5 MONTHLY AVERAGE WATER TEMPERATURES FOR THE LOWER HUDSON RIVER ESTUARY IN THE VICINITY OF BOWLINE POINT, 1973-1976[a]

	Monthly Average Temperatures in Degrees C											
Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1973	--	0.0	2.8	--	12.0	21.9	24.9	26.9	24.3	18.6	11.4	5.8
1974	--	--	--	8.6	15.1	20.9	24.6	25.9	22.0	16.3	12.2	3.8
1975	2.4	1.3	3.2	6.9	16.4	22.7	25.9	26.0	21.2	16.6	11.3	4.0
1976	0.2	2.0	4.3	10.3	15.2	21.2	25.4	25.2	22.3	14.0	6.9	2.4
4-yr avg												
C	1.3	1.1	3.4	8.6	14.7	21.7	25.2	26.0	22.4	16.4	10.4	4.0
(F)	(34.3)	(34.0)	(38.1)	(47.5)	(58.5)	(71.1)	(77.4)	(78.8)	(72.3)	(61.5)	(50.7)	(39.2)

(a) Data from LMS (1978:p. 4-4). Temperatures recorded in conjunction with biological sampling; the values presented represent the mean for all depths (surface, middepth, and bottom) at near-field river biological stations, and include residual heat from the Bowline Point plant and other generating stations operating at the time.

Note: Dash (--) indicates no data.

mum and maximum monthly average values over the 14-year data base (1959-1969, and 1973-1976), from Peekskill and Bowline Point near-field measurements, respectively, is presented in Table 3.1-6 and graphically shown in Figure 3.1-5.

3.1.3.3 Dissolved Oxygen

Dissolved oxygen (DO) in natural water bodies is essential for the maintenance and well-being of most aquatic biota, and is influenced by physical, chemical, and biological factors. Among those factors expected to be of greatest importance in the Hudson River estuary are temperature, salinity, turbulence, photosynthesis, and respiration. As water temperatures change, DO levels varyinversely as a consequence of decreasing oxygen solubility with increasing temperature.

Dissolved oxygen concentrations in the Hudson River estuary vary longitudinally within the system. Between MP 153 and MP 100 the DO concentration steadily declines from the Troy Dam to the Albany area, then recovers near MP 100. From MP 100 to MP 30 the DO concentration is consistently high (>5.0 mg/liter), although at MP 30 a sag begins that extends to the Battery in New York City before a rise to the ocean.

In recent years (1973-1976), the DO concentration in the vicinity of Bowline Point has ranged from 5.0 to 13.5 mg/liter with some seasonal variation; maximum values occur in winter and early spring, and minimum values in middle to late summer.

TABLE 3.1-6 TEN-YEAR MEAN MONTHLY AVERAGE WATER TEMPERATURES (1959-1969), AND EXTREME MONTHLY AVERAGE TEMPERATURE VALUES OVER 14-YEAR DATA BASE (1959-1969 AND 1973-1976) FOR THE LOWER HUDSON RIVER ESTUARY IN THE VICINITY OF BOWLINE POINT

	Monthly Average Temperatures in Degrees C (F)											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
10-yr mean(a)	1.1 (34.0)	0.6 (33.1)	1.6 (34.9)	6.9 (44.4)	13.9 (57.0)	20.1 (68.2)	24.3 (75.7)	24.7 (76.5)	22.7 (72.9)	17.9 (64.2)	11.5 (52.7)	4.7 (40.5)
Minimum(b)	0.0 (32.0)	0.0 (32.0)	0.6 (33.1)	6.1 (43.0)	11.7 (53.1)	18.9 (66.0)	23.3 (73.9)	23.9 (75.0)	21.0 (69.8)	14.1 (57.4)	6.9 (44.4)	2.4 (36.3)
Maximum(b)	4.3 (39.7)	2.8 (37.0)	4.3 (39.7)	10.3 (50.5)	16.4 (61.5)	22.7 (72.9)	25.9 (78.6)	26.9 (80.4)	25.0 (77.0)	19.4 (66.9)	12.9 (55.2)	7.6 (45.7)

(a) Data from USGS records for Peekskill, New York, October 1959-February 1969 (see Table 3.1-4).

(b) Data from USGS records for Peekskill, New York (1959-1969), and Bowline Point near-field area (1973-1976) (see Tables 3.1-4 and 3.1-5).

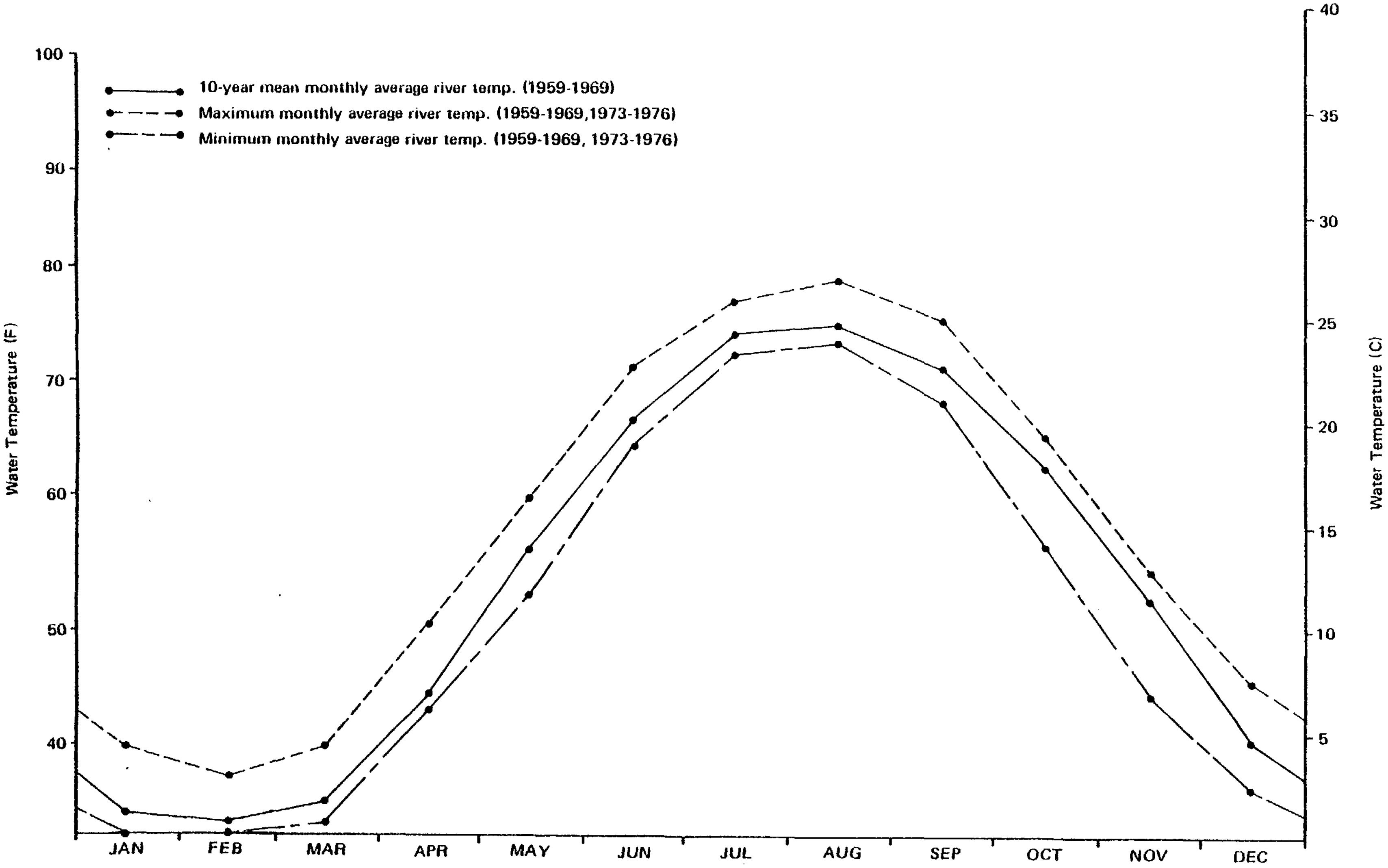

Figure 3.1-5. Temperature curves depicting long-term monthly average water temperatures and extremes for the lower Hudson River estuary in the vicinity of Bowline Point.

3.2 PLANT DESCRIPTION AND OPERATIONAL CHARACTERISTICS*

3.2.1 Description

The Bowline Point Generating Station consists of two completely enclosed oil- and gas-fired steam-electric units, each of which has a nominal net generating capability rating of 600 MWe and a maximum gross capability of 622 MWe. Unit 1 has been in operation since September 1972 and Unit 2 began commercial operation in May 1974. Each unit has a separate once-through cooling water system that transfers waste heat from the condensers to the Hudson River. Cooling water for each unit is drawn from Bowline Pond (Figure 3.2-1), which is connected with the Hudson River estuary via a pond inlet approximately 219 ft wide at the water surface and 16.5 ft deep at the mean low water level (McFadden 1977:p. 2.97). After passing through the condensers, the cooling water is then discharged back into the river through separate offshore, submerged multiport diffusers. The circulating cooling water arrangements for both units are virtually identical.

3.2.2 Intake and Discharge Systems

Cooling water for each unit's condensers and for the service-water system is pumped from an intake structure located on the northeast shore of Bowline Pond, (Figure 3.2-1). The reinforced concrete intake structure is 140 ft wide and about 27 ft deep at mean water level.

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* Material in this section, unless otherwise referenced, is summarized from the report entitled "Bowline Point Generating Station Hydrothermal Analysis" (LMS 1978).

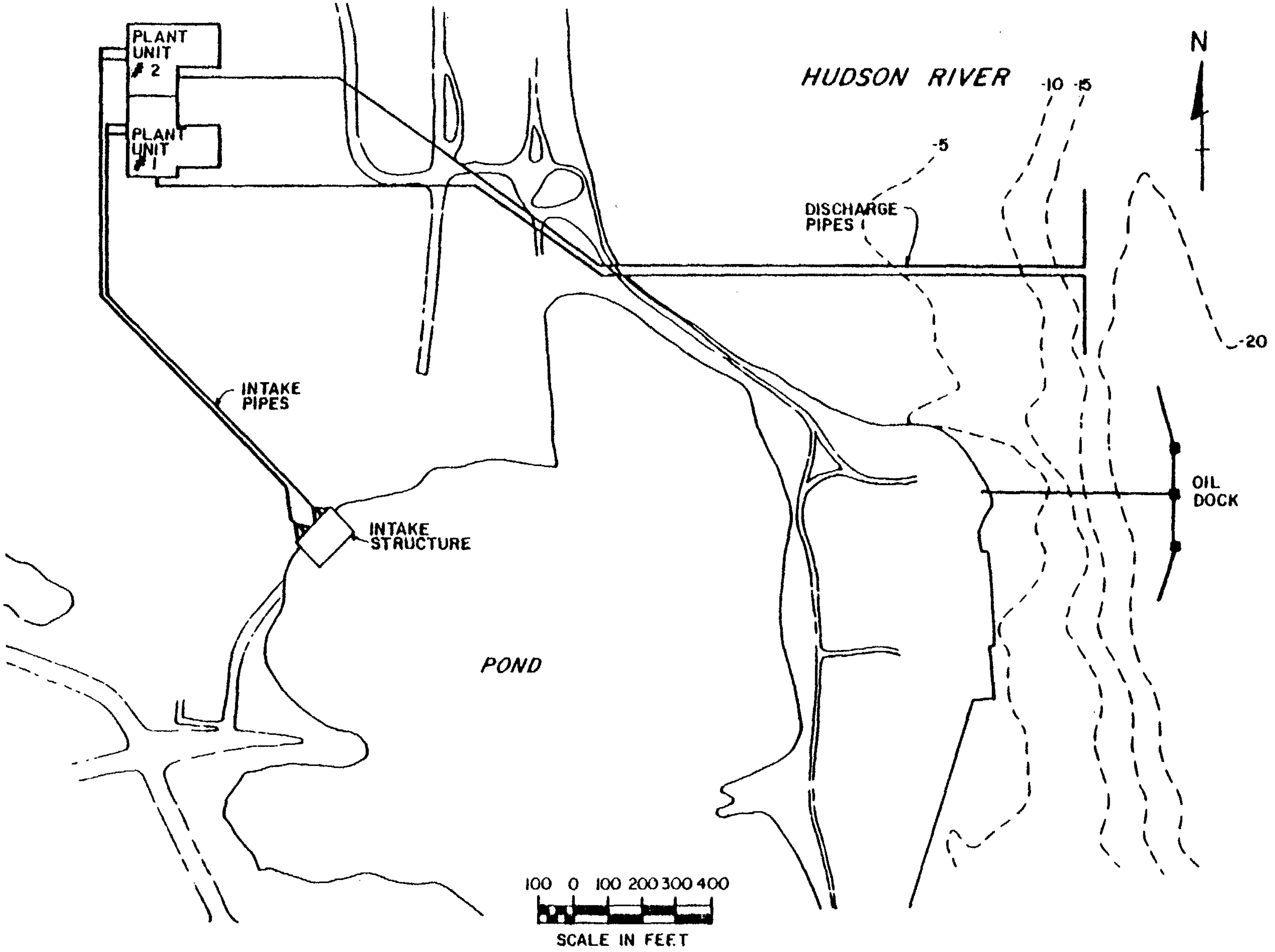

Figure 3.2-1. General plan of Bowline Point Generating Station circulating water system (from LMS 1977: Figure II-2).

The structure is divided into six bays, three for each of the two generating units. Each bay is about 16 ft wide and is equipped with (in order) a bar trash rack at the entrance, a deicing bubbler, a traveling screen and screenwash pump, a chlorine solution diffuser, and a 185,000 gal/minute circulating water pump (Figure 3.2-2). The bays for each unit interconnect downstream of the traveling screens to minimize waterflow velocity when less than three circulating water pumps are operating. Chlorine solution diffusers are located downstream of these interconnecting ports. Intake structure equipment is enclosed in a heated, metal frame building (ORU 1977:pp. 2.2-1 - 2.2-2).

Cooling water from both units of the Bowline Point plant is discharged back into the Hudson River estuary perpendicular to the direction of river flow through multiport, high-velocity diffusers. The diffuser headers are located in the river approximately 2,500 ft east of the plant, and approximately 1,400 ft offshore (Figure 3.2-1). Each header consists of a 220-ft long steel pipe (5/8-in. wall, 10.5-ft inside diameter) that contains a total of eight discharge nozzles (Figure 3.2-3). Each nozzle is 3 ft in diameter at its outlet, and angled 5 degrees upward from the horizontal to minimize scouring of the river bottom. The average depth to the centerline of the nozzle ports is 15 ft below mean low water (MLW); the average depth to the river bottom in the immediate area of the diffuser headers is 21 ft (MLW). Since there are no control valves in the diffusers, the discharge flow is a function of the number of circulating water pumps in operation. When all pumps are operating (i.e., three pumps per unit), the initial jet velocity from the diffuser nozzles is 15 fps. This combination of an offshore location and a high velocity, submerged diffuser design for the plant's cooling water discharge structure was selected after extensive study indicated that such a design would provide maximum dilution of the

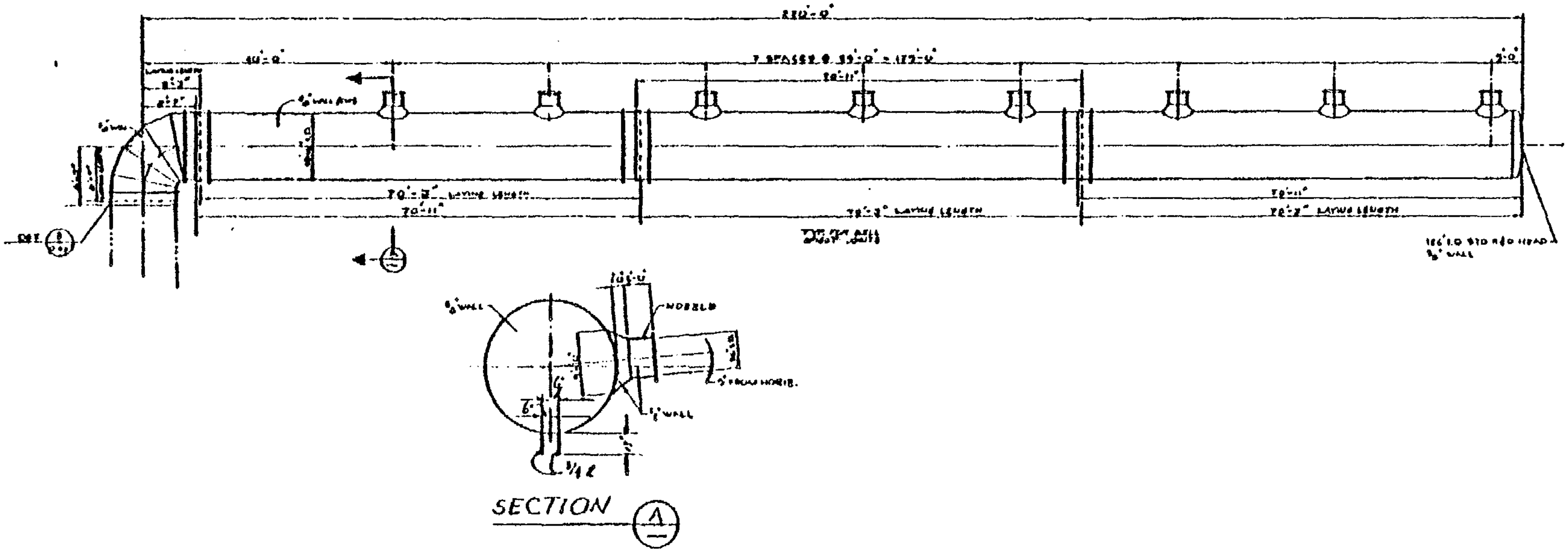

Figure 3.2-3. Circulating water discharge header, Bowline Point Generating Station.

thermal discharge and would minimize the exposure of aquatic organisms to high temperature regions.

A summary of operational data for the Bowline Point plant's cooling water system is presented in Table 3.2-1.

3.2.3 Cooling Water Flow Characteristics

Three circulating water pumps are associated with each unit, and at least two pumps per unit must be kept running to permit reliable and safe operation; pump operation can further be controlled by throttling. Consequently, the three acceptable methods of operation for each unit are the three-pump mode, the two-pump mode, and the two-pump-throttled mode. Based on circulating water pump characteristic curves and circulating water system head loss curves (LMS 1978:p. 2-7), the cooling water flows and total discharge head (TDH) associated with these operational modes are as follows:

	Cooling Water Rate Per Unit			
No. of Pumps	Per Minute (gpm)	Per Hour (gph)	Per Day (gpd)	TDH (ft)
3	384,000	23,040,000	552,960,000	35.0
2	316,000	18,960,000	455,040,000	22.4
2 (throttled)	257,000	15,420,000	370,080,000	35.0

Each circulating water pump tends to pump more water as the total system flow and head losses decrease. During the warmest months (i.e., the last 2 weeks in June through the first 2 weeks in September), three pumps are run to minimize temperature rises across the condenser and within the receiving water. For the remainder of the year, only two pumps are run to meet all operating requirements. Under restrictive operating constraints for aquatic studies,

TABLE 3.2-1 BOWLINE POINT GENERATING STATION COOLING WATER SYSTEM OPERATIONAL DATA(a)

Operating Characteristics	Unit 1 & 2 (Each)(b)
Nominal net generating capacity rating, MWe	600
Maximum gross generating capacity, MWe	622
Cooling water flow rate, gpm	
Condenser	375,620
Service water	8,480
Heat rejection rate, Btu/hr	2.82 x 109
Cooling water temperature rise, F (C)	14.9 (8.3)
Intake Characteristics	
Type of intake	Shoreline
Maximum approach velocity to the screens, fps	0.77
Pipe diameter from intake to condenser, ft	10.5
Total flow, gpm (cfs)	384,100 (856)
Outfall Characteristics	
Length of main tunnel from existing Hudson River shoreline, ft	1,400
Tunnel velocity, fps	9.9
Length of diffuser, ft	220
Number of diffuser ports	8
Inside diameter of diffuser ports, ft	3
Port spacing, ft	25
Initial jet velocity, fps	15
Total diffuser flow, gpm	384,100
Average depth of port centerline below mean low water, ft	15
Average depth to river bottom below mean low water, ft	21
Port temperature rise above river ambient, F (C)	14.9 (8.3)

(a) From LMS 1978:Table 2-1.

(b) Values presented based on full capacity operation, all circulating water pumps operating.

the circulating water system has been operated with two pumps running and the condenser discharge valve throttled to reduce flows to a minimum without jeopardizing generating system reliability. Although the two-pump-throttled mode is not optimal from an operating point of view, it is an option available to reduce river flow through the system during the cooler months of the year.

3.2.4 Cooling Water Temperature Rises

The rise in cooling water temperature is inversely proportional to the rate f of cooling water flow and directly proportional to the rate of heat rejection (LMS 1978:pp. 2-8 - 2-12), which itself is a function of megawatt output. Based upon actual temperature data, curves of delta-T versus net megawatt output (Figure 3.2-4) were calculated using linear regression analysis. Although the developed relationships are based on spring-summer plant operation, they serve as a conservative estimate for the entire year, since during the winter the plant discharges less total heat to the river.

For purposes of evaluating the effects of the Bowline Point plant's thermal discharge, maximum cooling water temperature rises (delta-T) were estimated using the relationships in Figure 3.2-4 and an average recirculation rate of 13 percent, as determined from field thermal survey data (ORU 1977:p. 3.1-49). Based on these estimates, the maximum delta-T at full plant operating capacity (600 MWe) is 8.2 C (14.8 F) during the period 15 June - 15 September (three-pump mode), and 10.0 C (18.1 F) from 16 September to 14 June (two-pump mode). The maximum discharge temperatures that would generally be expected to occur at full generation during periods of typical and unusually warm ambient river temperature conditions are presented in Table 3.2-2 and graphically shown in Figure 3.2-5.

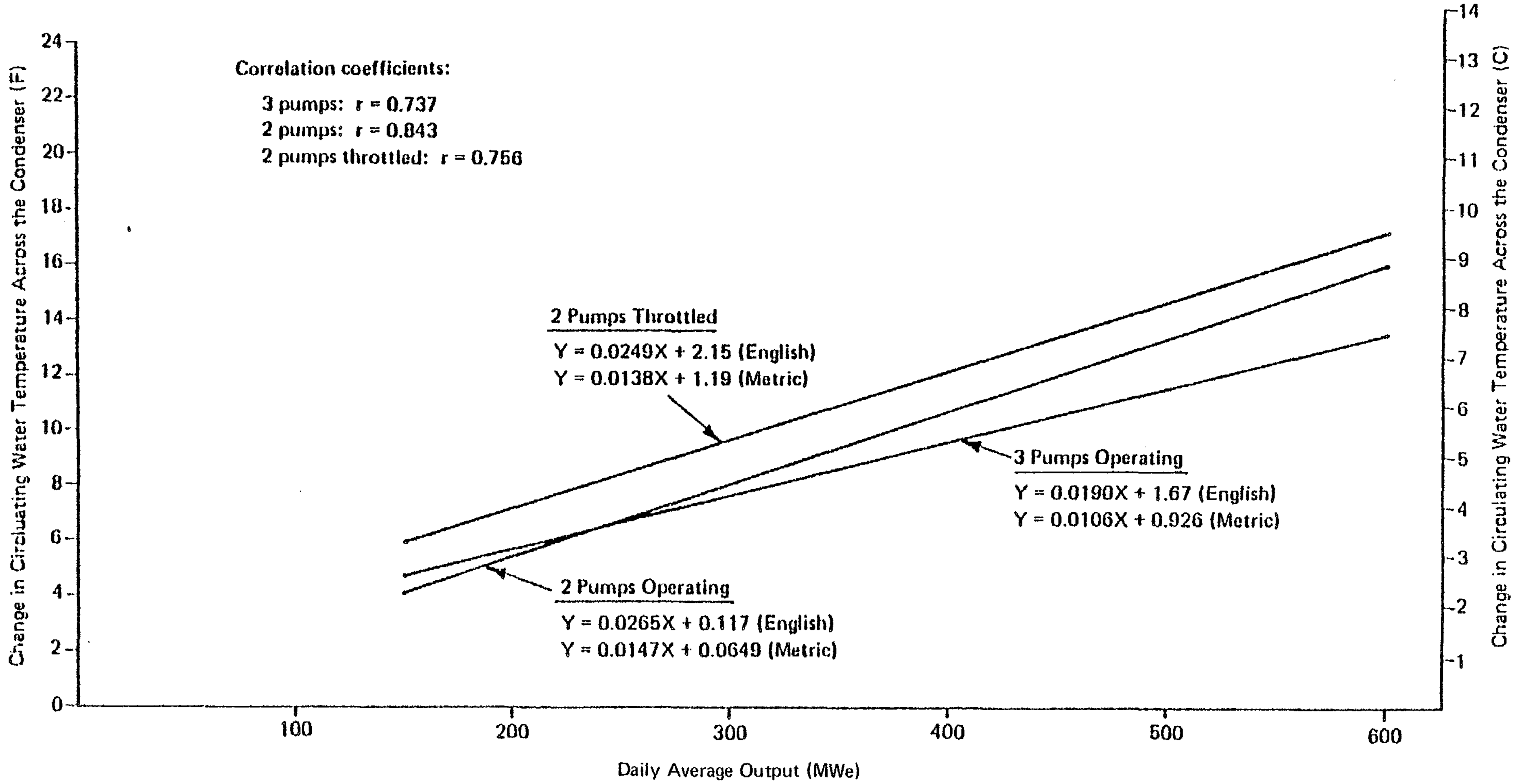

Figure 3.2-4. **Relationship between circulating water temperature rise (condenser delta-T) and daily average plant output for the Bowline Point Generating Station's three operational modes (from LMS 1978: Figure 2-8).**

TABLE 3.2-2 BOWLINE POINT GENERATING STATION THEORETICAL MAXIMUM DISCHARGE TEMPERATURES FOR TYPICAL AND EXTREME AMBIENT WATER TEMPERATURE CONDITIONS

Month	Mean(a) Monthly Average Temperature		Theoretical(b) Mean Monthly Average Discharge Temperature		Maximum(c) Monthly Average Temperature		Theoretical(b) Maximum Monthly Average Discharge Temperature	
	C	F	C	F	C	F	C	F
JAN	1.1	34.0	11.1	52.0	4.3	39.7	14.3	57.7
FEB	0.6	33.1	10.6	51.1	2.8	37.0	12.8	55.0
MAR	1.6	34.9	11.6	52.9	4.3	39.7	14.3	57.7
APR	6.9	44.4	16.9	62.4	10.3	50.5	20.3	68.5
MAY	13.9	57.0	23.9	75.0	16.4	61.5	26.4	79.5
JUN	20.1	68.2	30.1/28.3	86.2/82.9(d)	22.7	72.9	32.7/30.9	90.9/87.6(d)
JUL	24.3	75.7	32.5	90.5	25.9	78.6	34.1	93.4
AUG	24.7	76.5	32.9	91.2	26.9	80.4	35.1	95.2
SEP	22.7	72.9	30.9/32.7	87.6/90.9(d)	25.0	77.0	33.2/35.0	91.8/95.0(d)
OCT	17.9	64.2	27.9	82.2	19.4	66.9	29.4	84.9
NOV	11.5	52.7	21.5	70.7	12.9	55.2	22.9	73.2
DEC	4.7	40.5	14.7	58.5	7.6	45.7	17.6	63.7

(a) Data from USGS records for Peekskill, New York, October 1959 - February 1969 (see Table 3.1-6).

(b) Maximum discharge temperature rise is 8.2 C (14.8 F) from 15 June - 15 September (three pump operating mode), and 10.0 C (18.1 F) from 16 September - 14 June (two pump operating mode); assumes continual plant operation at maximum capacity.

(c) Data from USGS records for Peekskill, New York (1959-1969), and Bowline Point near-field area (1973-1976) (see Table 3.1-6).

(d) Delta-T changes when pumping rate changes in midmonth.

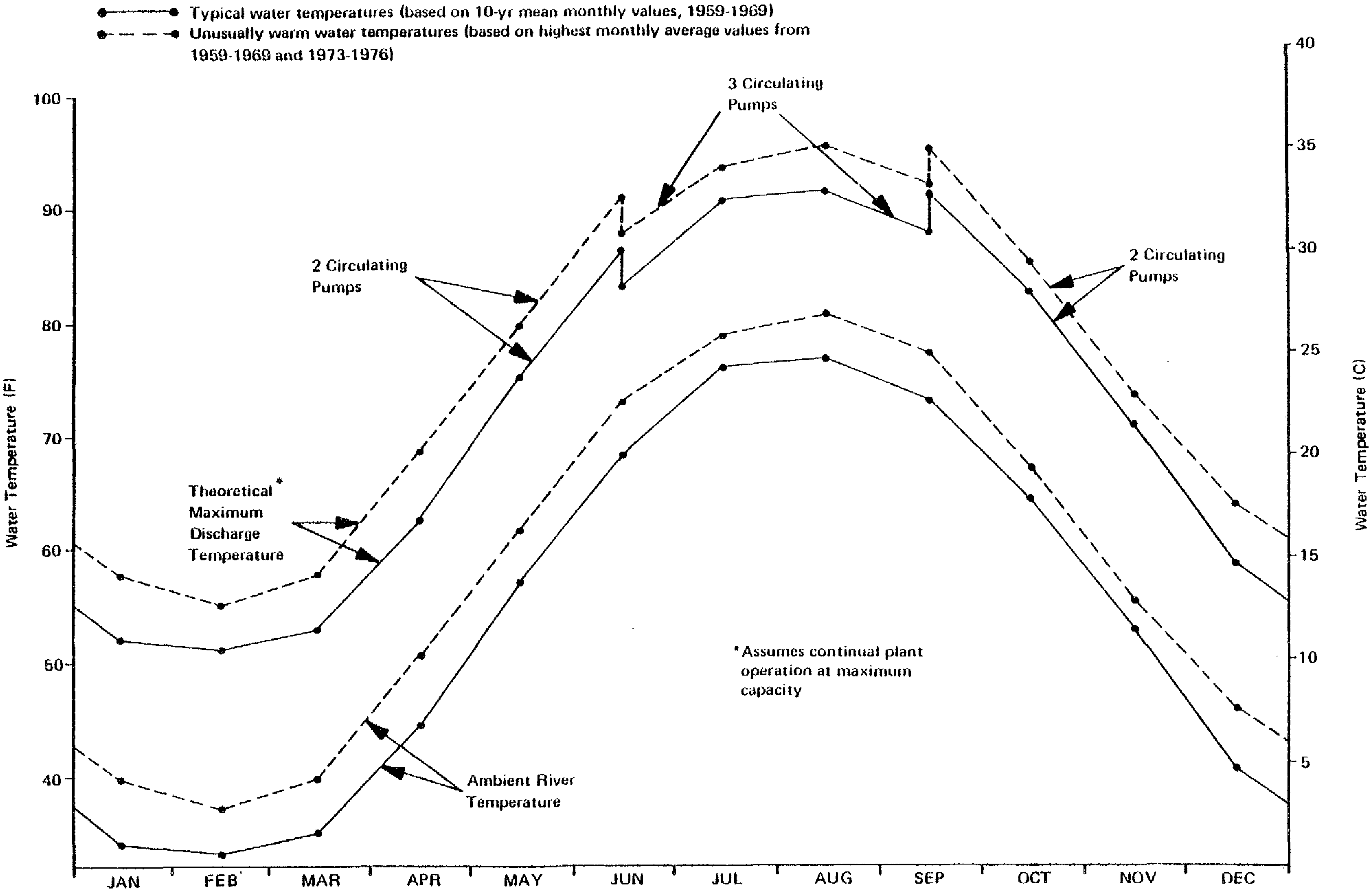

Figure 3.2-5. Temperature curves depicting typical and unusually warm ambient water temperatures for the Hudson River estuary in the vicinity of the Bowline Point Generating Station, and corresponding maximum discharge temperatures for the plant's cooling water system.

3.2.5 Historical Plant Loads

3.2.5.1 Historical Summary of Net Generation

An hourly summary of historical net generation for the Bowline Point Generating Station by unit and for the entire plant for April through August (1973-1976) is presented in ORU (1977:Appendix 2.1A); these months represent the principal spawning and nursery period for most Hudson River fish species, and include the time of year when highest ambient river temperatures occur (i.e., July and August). Because of the day/night biological implications, the summary is segmented into daytime output (0600-2100 hours) and nighttime output (2100-0600 hours). The following table summarizes total plant monthly capacity factors for the months of April through August, 1973-1976:

Month	Bowline Point Plant Capacity Factors (Percent)			
	1973	1974	1975	1976
APR	69.8	14.0(a)	65.2	61.7
MAY	74.2	12.7(a)	33.7	62.7
JUN	66.5	27.7(a)	50.7	51.1(b)
JUL	63.9	47.9	66.1	47.1(b)
AUG	68.6	71.0	71.4	37.5(b)

(a) Startup of Unit 2 and scheduled outage of Unit 1 occurred during this period.

(b) Scheduled outages of Units 1 and 2 occurred during this period.

These capacity factors indicate that typical average plant output is generally below maximum generating capability. Discharge temperatures, therefore, are not normally as high as maximum values shown in Table 3.2-2 and Figure 3.2-5.

3.2.5.2 Representative Diurnal Generation Profile

Historical net generation data for the Bowline Point plant (ORU 1977:Appendix 2.1A) were analyzed to provide two basic descriptions of the daily generation cycle: representative diurnal generation profiles and cumulative distributions of plant capacity factors for each hour of the day. Diurnal generation profiles for each month from April through August are presented in ORU (1977: Appendix Tables 2.1B-1 - 2.1B-40). Daily cycles of plant capacity factors are representative of operating days on which the maximum and minimum hourly generating loads were at least 80 percent and 20 percent, respectively, of total plant generating capacity. The profiles show that the plant typically operates at minimum levels of 20-30 percent of capacity in the early morning hours, and reaches maximum levels of 85-95 percent of capacity in midafternoon.

To establish typical monthly plant factors for daytime operation (0600-2100 hours) and for nighttime operation (2100-0600 hours), each month's data for 1975 and 1976 were averaged over the respective time periods presented in ORU (1977:Appendix Tables 2.1B-1 - 2.1B-40). The resulting day/night monthly plant capacity factors are summarized below:

	Representative Monthly Plant Capacity Factors (Percent)	
Month	Daytime (0600-2100 hours)	Nighttime (2100-0600 hours)
APR	81.2	52.9
MAY	79.9	59.6
JUN	80.8	61.8
JUL	84.3	71.1
AUG	78.1	61.7

The plant normally operates at less than 90 percent capacity 30-60 percent of the time during peak load hours, but less than 70 percent capacity 80-90 percent of the time during hours of low generation.

3.2.5.3 Plant Outages

The hourly summary of historical net generation (ORU 1977:Appendix 2.1A) indicates three types of outages which result in zero operation for either unit or both units:

1. A forced outage (designated by an "F" in the data summary) is an unanticipated trip or shutdown of a unit or both units.
2. A planned outage (designated by a "P") is an anticipated outage of a unit (never two units) for annual maintenance or overhaul that is scheduled several months in advance.
3. A scheduled outage (designated by an "S") is a semianticipated outage of a unit that is scheduled only a few days before shutdown, generally to perform necessary repairs or unanticipated maintenance.

Forced and scheduled outages occur naturally during day-to-day plant operation and cannot be specifically allocated to a generation schedule. However, planned outages can be allocated to a set time period and frequency. A schedule of planned maintenance dates (1977-2015) by unit is presented in ORU (1977:p. 2.1-19).

3.3 DISCHARGE EFFECTS ON THE RECEIVING WATER*

3.3.1 Near-Field Hydrothermal Effects

This subsection summarizes the results of field thermal surveys designed to define the thermal characteristics and extent of the heated plume created by initial mixing of condenser cooling water discharged by the Bowline Point plant. All surveys included were conducted after the plant began commercial operation in 1972 (Unit 1 went online on 8 September 1972 and Unit 2 on 13 May 1974). Field survey results, as well as preoperational mathematical and hydraulic model predictions relating to New York State criteria governing thermal discharges are presented to evaluate compliance with these criteria. Information is also provided which depicts the velocity-temperature patterns in the immediate vicinity of the diffuser ports, and temperature decay with time of a water particle moving from the discharge port to the 1 C (1.8 F) isotherm.

3.3.1.1 Thermal Characteristics and Dimensions of the Discharge Plume

The results of 14 thermal plume surveys conducted in the vicinity of the Bowline Point plant since 1972 are detailed in LMS (1974, 1975a, 1975b, 1975c, 1976a, and 1976b). Table 3.3-1 summarizes the results of these surveys showing ambient surface temperature, maximum observed surface temperature rise, dilution ratio, and percent surface width and cross-sectional area bounded by the 2.2 C (4 F) temperature rise isotherm of the plume as functions of various

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* Material in this section, unless otherwise referenced, is summarized in whole or in part from the report entitled "Bowline Point Generating Station Hydrothermal Analysis" (LMS 1978) which provides additional detail on the effects of the Bowline Point plant's cooling water discharge on the temperature distribution of the Hudson River estuary.

TABLE 3.3-1 SUMMARY OF THERMAL SURVEYS, BOWLINE POINT GENERATING STATION AND VICINITY, SEPTEMBER 1972 - OCTOBER 1975(a)

Survey Date	Tidal Phase	Ambient Surface Temp. (F)	Maximum Surface Temp. Rise ΔT_{sm} (F)	Daily Average Plant Temp. Rise ΔT_o (F)		Dilution Ratio(b)		Daily Average Cooling Water Flow Rate (10^3 gpm)		Percent Surface Width Bounded by the Temp. Rise Isotherm (≥4 F)	Percent Cross-Sectional Bounded by Temp. Rise Isotherm (≥4 F)	Percent of Total Station Load (Based on Generation)
				Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2			
8 SEP 1972	Flood	75.0	3.4	12.0	NA	3.5	NA	316	NA	0.0	--	78.3
19 SEP 1972	HWS	74.0	3.1	10.5	NA	3.4	NA	384	NA	0.0	--	77.2
	Ebb	74.0	3.5	--	NA	3.0	NA	--	NA	0.0	--	77.2
20 SEP 1972	Ebb	71.0	3.6	11.5	NA	3.2	NA	316	NA	0.0	--	78.2
10 JAN 1973	Flood	32.5	5.5	13.0	NA	2.3	NA	384	NA	--	--	96.7
24 AUG 1973	LWS	79.0	2.9	8.5	NA	2.9	NA	316	NA	0.0	0.1	52.3
13 SEP 1973	Flood	75.5	4.6	12.2	NA	2.7	NA	384	NA	0.1	1.9	98.3
	HWS	75.5	4.3	12.2	NA	2.8	NA	384	NA	0.1	0.6	98.3
	Ebb	75.0	3.3	12.2	NA	3.7	NA	384	NA	0.0	0.8	98.3
14 SEP 1973	LWS	75.5	3.7	11.9	NA	3.2	NA	384	NA	0.0	1.6	>99.0
	Flood	75.5	4.0	11.9	NA	3.0	NA	384	NA	0.0	1.0	>99.0
	HWS	75.0	2.9	11.9	NA	4.1	NA	384	NA	0.0	0.8	>99.0
2 AUG 1974	Flood	77.5	5.1	10.0	--	2.0	--	316	316	2.6	1.9	68.8
	HWS	78.0	4.2	10.0	--	2.4	--	316	316	0.3	0.5	78.7
	Ebb	77.5	5.0	10.0	--	2.0	--	316	316	0.5	1.3	95.5
29 AUG 1974	Ebb	79.5(c)	3.5	13.0	12.0	3.6		316	384	0.0	0.1	99.0
	LWS	79.5(c)	4.6	13.0	12.0	2.7		316	384	2.8	3.0	98.5
	Flood	79.0	5.7	13.0	12.0	2.2		316	384	4.9	2.8	98.7
	HWS	79.5	3.7	13.0	12.0	3.4		316	384	0.1	0.4	98.3
7 NOV 1974	Ebb	57.0	4.4	7.0	10.0	1.9		316	316	0.6	0.7	75.8
	LWS	57.0	4.3	7.0	10.0	2.0		316	316	0.5	0.8	75.9
	Flood	57.0	5.4	7.0	10.0	1.6		316	316	2.1	0.7	76.0
	HWS	57.5	2.5	7.0	10.0	3.4		316	316	0.0	0.0	76.2
15 APR 1975	Ebb	41.0	3.8	14.0	(d)	3.7	(d)	257	(d)	0.0	0.0	40.1
	LWS	41.0	6.5	15.0	(d)	2.3	(d)	257	(d)	4.1	2.8	40.5
	Flood	41.5	6.7	15.0	3.0	2.2	(e)	257	257	1.4	1.3	56.5
	HWS	42.0	3.3	15.0	(d)	4.6	(d)	257	(d)	0.0	0.6	40.7

(a) From LMS 1978:Table 4-2 (p. 4-20).
(b) Dilution ratio = (Average plant temperature rise (F))/(maximum surface temperature rise (F)); unless otherwise specified (see (e)).
(c) Maximum tabled values.
(d) Off line.
(e) Dilution ratio calculated using the higher of the two delta-T_o's.

Note: NA indicates not applicable since Unit 2 was under construction until 13 May 1974.
-- indicates not available.

TABLE 3.3-1 (CONT.)

Survey Date	Tidal Phase	Ambient Surface Temp. (F)	Maximum Surface Temp. Rise ΔT_{sm} (F)	Daily Average Plant Temp. Rise ΔT_o (F) Unit 1	Daily Average Plant Temp. Rise ΔT_o (F) Unit 2	Dilution Ratio[a] Unit 1	Dilution Ratio[a] Unit 2	Daily Average Cooling Water Flow Rate (103 gpm) Unit 1	Daily Average Cooling Water Flow Rate (103 gpm) Unit 2	Percent Surface Width Bounded by the Temp. Rise Isotherm (≥4 F)	Percent Cross-Sectional Bounded by Temp. Rise Isotherm (≥4 F)	Percent of Total Station Load (Based on Generation)
18 JUN 1975	HWS	72.5	2.9	15.0	13.0	4.9		257	257	0.0	0.0	86.7
	Ebb	73.0	2.6	15.0	0-3.0	5.8	(d)	257	0-257	0.0	0.0	50.7
	LWS	73.0	5.6	16.0	12.0	2.5		257	257	1.5	1.3	85.7
	Flood	73.5	7.7[b]	16.0	16.0	2.2		257	257	2.4	3.7	93.8
18 AUG 1975	Flood	78.5	5.9	15.0	14.5	2.5		316	316	2.9	2.0	93.3
	HWS	79.0	3.0	15.5	14.5	5.0		316	316	0.0	0.0	93.4
	Ebb	79.0	3.4	15.5	14.5	4.5		316	316	0.0	0.0	92.9
	LWS	78.5	6.1	15.5	14.0	2.4		316	316	7.9[b]	5.5[b]	93.3
28 OCT 1975	HWS	57.0	2.4	14.0	(c)	5.6	(c)	316	(c)	0.0	0.0	35.4
	Ebb	57.0	2.5	14.0	(c)	5.8	(c)	316	(c)	0.0	0.0	40.6
	LWS	57.0	5.4	17.0	(c)	3.5	(c)	316	(c)	0.9	0.9	47.3
	Flood	57.0	4.9	17.0	(c)	3.5	(c)	316	(c)	1.9	0.6	45.8

(a) Dilution ratio = (Average plant temperature rise (F))/(maximum surface temperature rise (F)); unless otherwise specified (see (d)).
(b) Maximum tabled values.
(c) Off line.
(d) Dilution ratio calculated uisng the higher of the two delta-T_o's.

Note: NA indicates not applicable since Unit 2 was under construction until 13 May 1974.
-- indicates not available.

plant parameters. The 2.2 C (4 F) temperature rise isotherm is used to represent the primary extent of the thermal plume because a determination of compliance with NYSDEC thermal criteria requires analyses of this isotherm, and because it approximately represents the zone of discharge as defined by the 30 September 1974 draft of the EPA 316(a) Technical Guidance Manual (EPA 1974: p. 22), i.e., 2 C (3.6 F) (Subsection 3.3.1.2).

As Table 3.3-1 illustrates, the surveys were performed during varying plant operation and temperature conditions. For example, circulating water flow ranged from 257,000 gpm (one unit online, throttled flow) to 700,000 gpm (two units online), and plant operating load varied from 35.4 percent to approximately full capacity. Temperature ranges associated with the discharge and/or receiving water were as follows:

Variable	Temperature Range C	Temperature Range F
Plant delta-T	1.7 - 9.4	3.0 - 17.0
Ambient river temp.	0.3(a) - 26.4	32.5(a) - 79.5
Delta-T_{sm}(b)	1.3 - 4.3	2.4 - 7.7
Max. plume surface temp.(c)	3.3 - 29.3	38.0 - 84.7

(a) Survey conducted before Unit 2 went online.
(b) Delta-T_{sm} = maximum surface temperature rise.
(c) Maximum surface plume temperature for a given survey = ambient river temperature + delta-T_{sm}.

Surface isotherm maps of the thermal plume for selected surveys conducted after May 1974 (when Unit 2 went online) are presented in LMS (1978:Appendix Figures A-1 - A-16). These surveys were chosen as being representative of fall (11 November 1974), spring (15 April 1975), late spring/early summer (18 June

1975), and summer (18 August 1975) seasons.* The chosen surveys represent the worst measured case for each season, i.e., the survey which indicated the largest plume area and/or warmest temperatures. Table 3.3-2 summarizes the areal and volumetric dimensions of the 2.2 C (4 F) and other temperature rise isotherms for the survey dates mentioned above. This table also presents the percentage of volume and surface area of the various plume isotherms within two tidal excursions (one upstream and one downstream) of the plant. The maximum surface area and volume bounded by the 2.2 C (4 F) isotherm were 50.5 and 170 acre-ft, respectively (18 June 1975; two-pump throttled mode). Because of the large surface area and volume of the river in the vicinity of the plant, and the rapid heat dilution caused by the high-velocity diffuser, the ratios of plume areas and volumes bounded by the 2.2 C (4 F) isotherm to river areas and volumes within two tidal excursions are very small averaging 1:1528 and 1:5620, respectively, for the 14 surveys (Table 3.3-3).

For purposes of evaluating possible biological effects of the Bowline Point plant's thermal plume (Chapters 4 and 5), the maximum areal and volumetric extent of the plume are taken from the 18 June and 18 August 1975 surveys (Table 3.3-2). These two surveys, conducted during summer ambient temperatures, represent the plume under near maximum capacity plant operation (approximately 93 percent) and at its largest dimensions for two critical pumping rates (i.e., two-pump throttled operating mode on 18 June 1975, and three-pump mode on 18 August 1975). In the winter, the plume is reduced by a decrease in the total amount of heat rejected to the river (LMS 1978:p. 2-9). Therefore, these sum-

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* No winter surveys were conducted after both units went online. When more than one survey was conducted during a season, the survey which showed the largest thermal influence was chosen.

TABLE 3.3-2 SUMMARY OF THE SURFACE AREA AND VOLUME OF THE BOWLINE POINT GENERATING STATIONS'S DISCHARGE PLUME WITH RESPECT TO THE 2.2 C (4 F) AND BOUNDING TEMPERATURE RISE ISOTHERMS(a)

Date	Tidal Phase	Temperature Rise Isotherm (>) F	Heat Load (Btu x 10^9/Day)		Surface Area (Acres)	Percent Surface Area(b)	Volume (Acre-ft)	Percent Volume(b)	Percent Capacity
			Unit 1	Unit 2					
7 NOV 1974	Ebb	3	26.5	48.0	0.83	0.012	3.56	0.002	75.8
		4			0.14	0.002	1.72	0.001	
		5			(c)	0.006	(c)	0.000	
	LWS	3	26.5	48.1	3.44	0.050	25.80	0.018	75.9
		4			0.16	0.002	0.41	0.001	
		5			(c)	0.000	(c)	0.000	
	Flood	3	26.5	48.2	11.50	0.163	36.70	0.025	76.0
		4			1.15	0.016	9.76	0.007	
		5			1.15	0.016	2.87	0.002	
	HWS	3	26.5	48.2	(c)	0.000	(c)	0.000	76.2
		4			(c)	0.000	(c)	0.000	
		5			(c)	0.000	(c)	0.000	
15 APR 1975	Ebb	3	39.4	0.0	8.27	0.117	26.60	0.018	40.1
		4			(c)	0.000	(c)	0.000	
		5			(c)	0.000	(c)	0.000	
	LWS	3	39.8	0.0	3.67	0.052	41.30	0.028	40.5
		4			1.84	0.026	6.43	0.004	
		5			0.92	0.013	4.13	0.003	
		6			0.92	0.013	3.21	0.002	
	Flood	3	40.1	15.4	7.58	0.107	111.00	0.076	56.5
		4			1.84	0.026	32.10	0.022	
		5			0.46	0.016	6.43	0.004	
		6			0.12	0.002	4.36	0.003	
		7			0.12	0.002	0.92	<0.001	40.7
	HWS	3	40.0	0.0	5.74	0.080	51.20	0.035	
		4			(c)	0.000	(c)	0.000	
		5			(c)	0.000	(c)	0.000	
18 JUN 1975	HWS	3	42.7	42.5	0.01	0.000	4.59	0.003	86.7
		4			(c)	0.000	(c)	0.000	
		5			(c)	0.000	(c)	0.000	
	Ebb	3	45.7	<3.8	(c)	0.000	(c)	0.000	50.7
		4			(c)	0.000	(c)	0.000	
		5			(c)	0.000	(c)	0.000	
	LWS	3	45.9	38.3	21.60	0.305	86.10	0.059	85.7
		4			0.92	0.013	9.20	0.006	
		5			0.18	0.002	3.10	0.002	
	Flood	3	46.3	45.5	141.00	1.995	604.00	0.410	93.8
		4			50.50	0.714	170.00	0.116	
		5			7.35	0.104	26.40	0.018	
		6			0.55	0.007	1.38	0.001	

(a) From LMS 1978:p. 4-22.

(b) Two tidal excursions (ebb and flood); surface area = 7,067 acres, volume = 146,987 acre-ft, see Table 3.3-3.

(c) No heat at the specified temperature rise.

TABLE 3.3-2 (CONT.)

Date	Tidal Phase	Temperature Rise Isotherm (>) F	Heat Load (Btu x 10^9/Day)		Surface Area (Acres)	Percent Surface Area[(a)]	Volume (Acre-ft)	Percent Volume[(a)]	Percent Capacity
			Unit 1	Unit 2					
18 AUG 1975	Flood	3	45.5	46.2	12.96	0.182	82.70	0.056	93.3
		4			7.35	0.104	75.80	0.052	
		5			1.38	0.020	12.60	0.009	
	HWS	3	46.0	45.8	0.69	0.010	1.84	0.001	93.4
		4			(b)	0.000	(b)	0.000	
		5			(b)	0.000	(b)	0.000	
	Ebb	3	45.8	45.5	11.00	0.155	59.70	0.041	92.9
		4			(b)	(b)	(b)	0.000	
		5			(b)	(b)	(b)	0.000	
	LWS	3	46.3	45.5	29.40	0.415	321.0	0.281	93.3
		4			10.10	0.143	113.00	0.077	
		5			3.67	0.052	32.10	0.022	
		6			0.69	0.010	2.99	0.002	

(a) Two tidal excursions (ebb and flood); surface area = 7,067 acres, volume = 146,987 acre-ft, see Table 3.3-3.

(b) No heat at the specified temperature rise.

TABLE 3.3-3 COMPARISON OF THE SURFACE AREA AND VOLUME BOUNDED BY THE ≥4 F (2.2 C) TEMPERATURE RISE ISOTHERMS OF THE BOWLINE POINT GENERATING STATION'S DISCHARGE PLUME WITH THE SURFACE AREA AND VOLUME OF THE HUDSON RIVER ESTUARY WITHIN TWO TIDAL EXCURSIONS

Values	Surface Area of ≥4 F Temperature Rise (Acres)	Ratio of Affected Area[a]	Volume of ≥4 F Temperature Rise (Acre-ft)	Ratio of Affected Volume[a]
Average[b]	4.63	1:1528	26.2	1:5620
Maximum	50.5	1:140	170.0	1:865

(a) Based on two tidal excursions - one upstream (1.9 mi), and one downstream (3.6 mi): Volume = 146,987 acre-ft; surface area = 7,067 acres (QLM 1971). Only 1975 and 1976 survey data used to calculate tidal excursions (LMS 1975b,c; 1976a).

(b) Average of 7 NOV 1974, 15 APR 1975, 18 JUN 1975, 18 AUG 1975; plant capacity ranged from 40 to 94 percent.

Note: From LMS (1978:Table 4-4).

mer surveys provide a larger than expected representation of the plume for the cooler months of the year.

3.3.1.2 Frequency Distribution of the Discharge Plume

The 30 September 1974 draft of the EPA 316(a) Technical Guidance Manual (EPA 1974:p. 22) defines zone of discharge as "...that portion of the receiving waters which is within the delta 2 C isotherm of the plume 30 percent or more of the time, as defined by data representing a period of at least a few months and preferably indicative of a complete annual cycle." To determine the Bowline Point plant's zone of discharge, the results of five thermal surveys (representing a total of 19 surface temperature rise isotherm mappings) were used; all of these surveys represented cases where plant loads (based on average daily generation) were 50 percent or more of maximum net plant capacity (1200 MWe). Four of the 19 isothermal maps showed surface temperature rises of less than 2 C (3.6 F). The dates on which the five selected surveys were made were: 2 August 1974; 29-30 August 1974; 7 November 1974; 18 June 1975; and 18 August 1975 (see Table 3.3-1 for plant operating conditions). The contours drawn in Figure 3.3-1 represent the portion of the receiving waterbody that falls within the 2 C (3.6 F) temperature rise isotherm 10, 20, 30, and 40 percent of the time. Similar analyses for the 3 C (5.4 F) and 4 C (7.2 F) isotherms indicated infrequent occurrence of these isotherms in the area of the Bowline Point plant discharge.

3.3.1.3 Comparison of Field Thermal Survey Results and Mathematical and Hydraulic Model Predictions with New York State Thermal Criteria

The maximum percentages of surface width and cross-sectional area of the Bowline Point plant's thermal plume within the 2.2 C (4 F) isotherm, as deter-

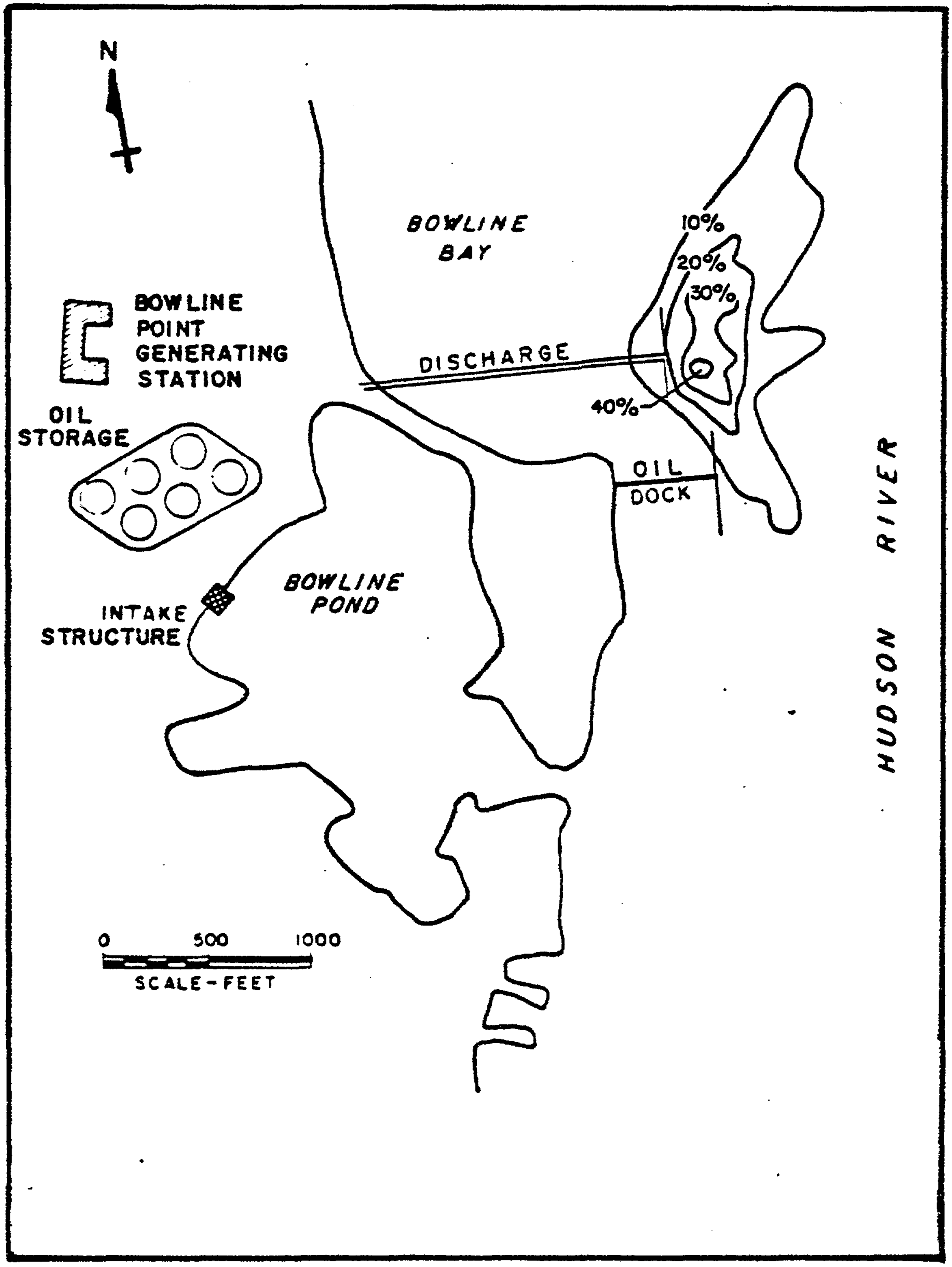


Figure 3.3-1. Bowline Point Generating Station zone of discharge as depicted by the frequency of occurrence of the 2 C (3.6 F) temperature rise isotherm (from LMS 1978:p. 4-25).

mined during field surveys, were 7.9 and 5.5 percent, respectively (Subsection 3.3.1.1, Table 3.3-1); both maxima occurred on 18 August 1975 when the plant was operating at near maximum capacity (93 percent). These values are considerably less than the New York State thermal discharge criteria for maximum river surface width and cross-sectional area bounded by the 2.2 C (4 F) temperature rise isotherm (i.e., 67 and 50 percent, respectively). Therefore, no violations of these criteria are expected to occur in the future at the Bowline Point plant.

A frequency plot of the maximum surface temperature rises (delta-T_{sm}) observed within the thermal plume of the Bowline Point plant (Figure 3.3-2) indicates that a delta-T_{sm} of 4.2 C (7.5 F) occurs less than 1 percent of the time. Based on this frequency of occurrence, in order for the New York State's 32.2 C (90 F) maximum surface temperature criterion to be violated (i.e., for temperatures $\geq$ 32.8 C [91 F] to occur) the ambient river temperature must exceed 28.6 C (83.5 F), a temperature which has never been observed in the Bowline Point area. Thus, no violation of this criterion is expected since the frequency with which the combination of maximum ambient temperature and maximum surface temperature rise would be likely to occur is very small.

Temperatures and dimensions of the discharge plume based on field survey measurements (Subsection 3.3.1.1) and preoperational mathematical, and hydraulic model predictions (LMS 1978:pp. 4-32 - 4-51), are presented in Table 3.3-4. Values listed under field observations are the maximum values measured during all thermal surveys conducted from 1972-1975 (Subsection 3.3.1.1, Table 3.3-1). Model predictions represent maximum values assuming full capacity operation for the two units at Bowline Point, five units at Lovett, and three units at

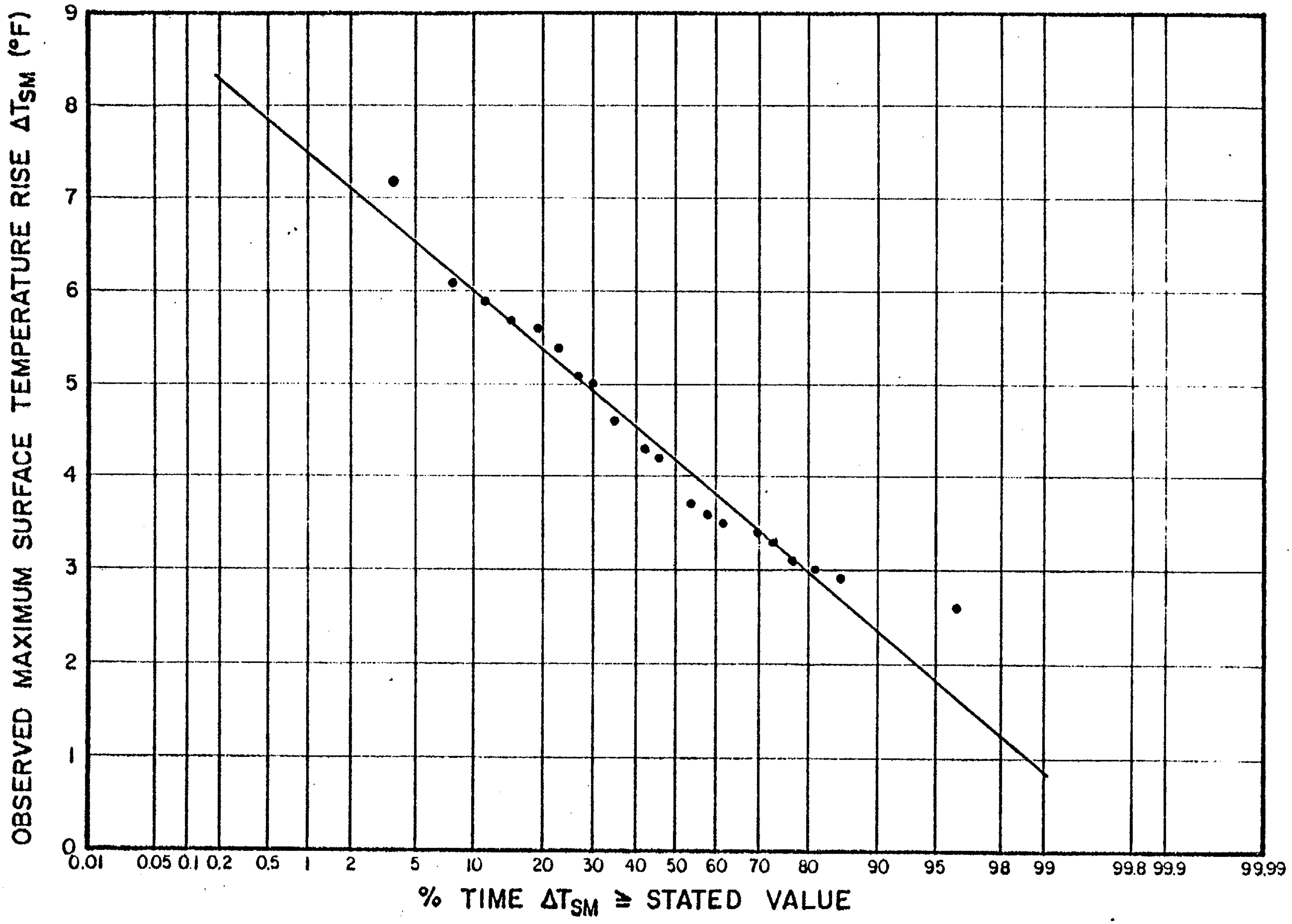


Figure 3.3-2. Frequency of maximum surface temperature rises observed within the Bowline Point Generating Station discharge plume (from LMS 1978:p. 4-20).

TABLE 3.3-4 THERMAL CHARACTERISTICS AND DIMENSIONS OF BOWLINE POINT GENERATING STATION'S DISCHARGE PLUME BASED ON FIELD SURVEY RESULTS AND MATHEMATICAL AND HYDRAULIC MODEL PREDICTIONS[a]

Parameter	Mathematical Model Predictions[b]	Hydraulic Model Predictions	Field Observation[c] (Date)	New York State Thermal Discharge Criteria
Maximum surface temperature rise (F)	5-7	3-5	7.7 (18 JUN 75)	--
Recirculation above base temperature (F)	1.0	0.6-1.35	--	--
Maximum surface temperature (F)	86.5-88.5(d)	82.6-85.35	84.7 (29 AUG 74)	90
Percent cross-sectional area bounded by the 4 F isotherm	5-7	--	7.5 (18 AUG 75)	50
Percent surface width bounded by the 4 F isotherm	23-31	3-10	7.9 (18 AUG 75)	67

(a) Mathematical and hydraulic model predictions assume 2 units at Bowline Point, 5 units at Lovett, and 3 units at Indian Point are operating at their maximum rated capacity; predicted values are based on an ambient river temperature of 79 F and are taken from QLM (1971).

(b) These values represent the maximum predictions obtained using four mathematical models (LMS 1978:pp. 4-32 - 4-42); upriver discharges resulted in an additional 1.5 F temperature rise above ambient.

(c) These values represent the maximum field observations as obtained from all triaxial thermal surveys (1972-1975).

(d) These values include a recirculation temperature rise of 1.0 F, and a temperature rise of 1.5 F from upriver discharges.

Note: Adapted from LMS 1978:p. 4-55.

Indian Point. Maximum surface temperatures were calculated from model results using a maximum ambient river temperature at Bowline Point of 26.1 C (79 F).

The mathematical models predicted higher maximum surface temperatures and percentage of surface width of the plume bounded by the 2.2 C (4 F) temperature rise isotherm than observed during field surveys. Hydraulic model results, however, generally compared closely with field data (Table 3.3-4). Models and field results both indicated maximum values less than the State's 32.2 C (90 F) temperature criterion. The maximum surface temperatures expected at Bowline Point, based on the mathematical models, were obtained by summing the predicted maximum surface temperature rises of 2.8-3.4 C (5-7 F), a recirculation temperature rise of 0.6 C (1.0 F) above ambient, and a temperature rise of 0.8 C (1.5 F) from upriver discharges. The maximum surface temperatures thus obtained ranged from 30.3 to 31.4 C (86.5 to 88.5 F), assuming an ambient river temperature of 26.1 C (79 F). Therefore, based on maximum mathematical model predictions, a violation of 32.2 C (90 F) maximum surface temperature criterion (i.e., for surface temperatures $\geq$ 91 F (32.8 C)) would occur at Bowline Point only when ambient river temperatures are 81.5 F (27.5 C) or higher. A comparison of the mathematical model results with the maximum observed field results shows the model predictions to be, on the whole, higher than expected. Field studies, as noted previously, have never indicated a violation of the 32.2 C (90 F) surface temperature criterion at Bowline Point, a situation that would occur only during the rare combination of maximum plant capacity, minimum dilution, and river temperatures of 28.6 C (83.5 F).

Based on model predictions and field survey measurements (Table 3.3-4), the maximum observed percentage of the river cross-sectional area within the 2.2 C (4 F) isotherm of the Bowline Point plant's thermal plume was 7.5 percent, which is well within the State's criterion of 50 percent. Although the predicted maximum percentage of river surface width within the 2.2 C (4 F) isotherm was 31 percent, this value is still much less than the State's thermal criterion of 67 percent; field data showed a maximum of 7.9 percent.

3.3.1.4 Immediate Discharge Velocity - Temperature Distribution

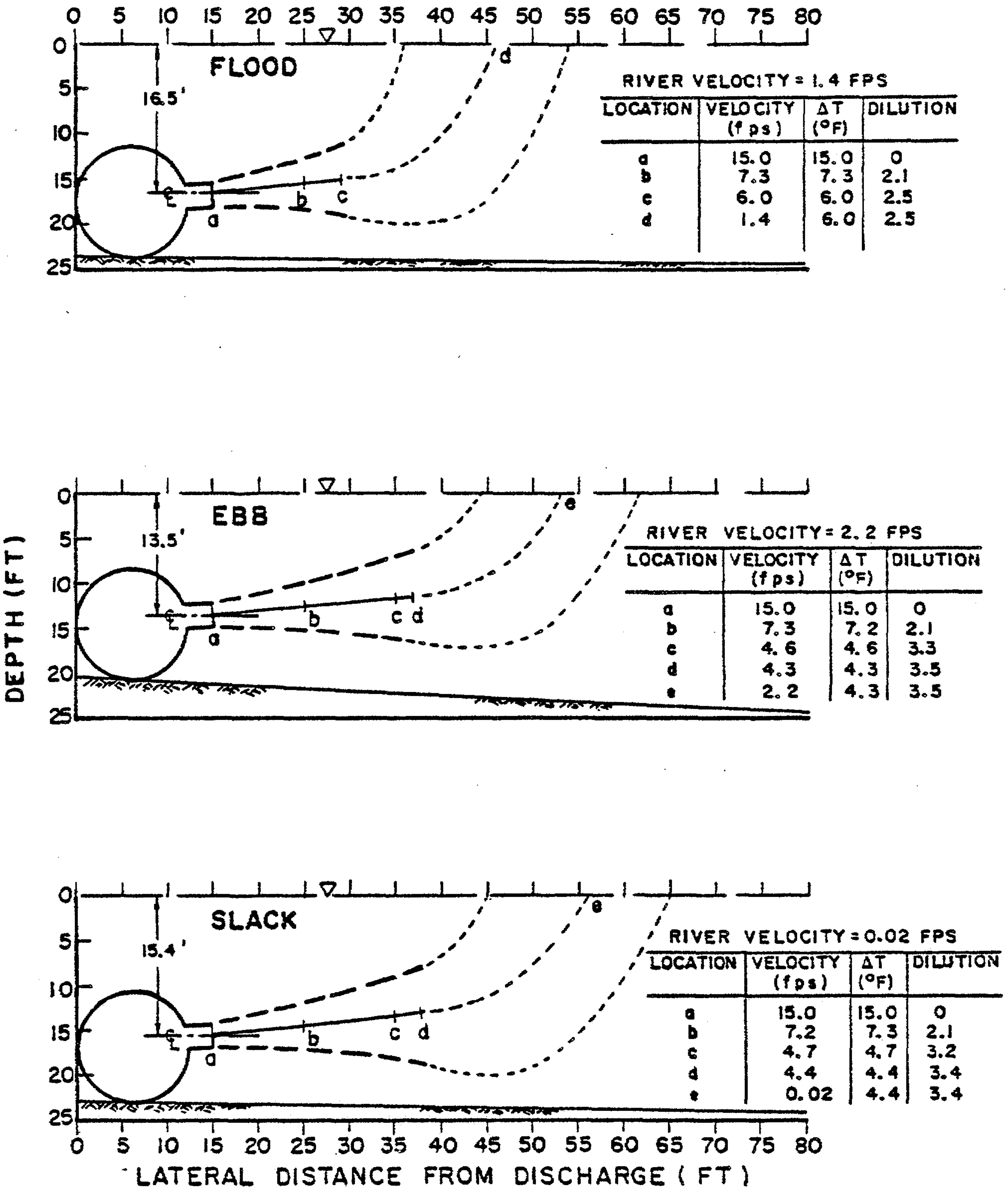
Before startup of the Bowline Point plant, a single submerged-jet mathematical model (LMS 1978:pp. 4-32 - 4-34) was used to calculate the temperature and velocity patterns from the plant's submerged discharge under flood, ebb, and slack tide conditions (LMS 1978:pp. 4-27 - 4-29). However, recent field data (Subsection 3.3.1.1) suggest that actual dilutions (maximum surface temperature/initial temperature) are less than the theoretical dilutions predicted by the model. Based on thermal plume surveys, the dilutions were as follows:

Tide	Dilution	
	Range	Average
Flood	1.6-3.5	2.52
Ebb	1.9-5.8	3.46
Slack	2.0-5.6	3.39

The field studies indicate that the submerged diffuser provides very good initial mixing; within the first 20-40 ft from the diffuser, the discharge has reached dilution ratios of 2-6. However, after the initial dilution, the discharge does not appear to entrain any new ambient water and is diluted little before reaching the river surface. Studies, such as Robideau (1972), indicate that for a discharge like that at the Bowline Point plant, there may be a limit on the amount of dilution water available. Although Robideau's data did not cover the lower range, this information did suggest that submerged discharges with a dimensionless water depth (H = submergence/port diameter) of less than 10 should have a very small effective water depth, i.e., the depth of water in which the discharge effectively mixes. The Bowline Point plant, with H = 4.5-5.5, should have little effective water depth and, after the initial mixing, would appear to be limited in the amount of dilution water that is available.

Using the submerged-jet model results and the average field dilutions, effective water depths of 1.25, 2.0, and 2.25 ft were calculated for flood, ebb, and slack tidal conditions, respectively. Small effective depths such as these are in the range of what might be expected from Robideau's study and would indicate that all the dilution (2-6) for the Bowline Point plant discharge occurs within the first 20-40 ft from the discharge port and that after this point the plume bubbles to the surface with little additional dilution taking place (Figure 3.3-3). As the discharge jet profile (Figure 3.3-3) shows, the velocity of the discharge flow within this region would decrease from 15 fps to approximately 4 fps, and the temperature of the discharge water would decrease from the condenser-induced temperature rise to within 2.4-3.3 C (4.3-6.0 F); these reductions would occur within approximately 5-10 seconds based on velocity-distance relationships. Once the velocity of the discharge flow diminishes to 4 fps, the plume then floats to the surface and decreases to ambient river current. Because little or no additional dilution occurs as the discharge water rises to the surface, the maximum surface temperature elevation, therefore, reflects the temperature rise above ambient of the discharge water upon reaching a velocity of 4 fps at 20-40 ft in front of the diffuser ports.

Although Figure 3.3-3 indicates that the temperature of the discharge water decreases to 2.4-3.3 C (4.3-6.0 F) above ambient by the time the jet flow has diminished to 4 fps, maximum surface temperature rises as much as 4.3 C



RIVER VELOCITY = 1.4 FPS

LOCATION	VELOCITY (fps)	ΔT (°F)	DILUTION
a	15.0	15.0	0
b	7.3	7.3	2.1
c	6.0	6.0	2.5
d	1.4	6.0	2.5

RIVER VELOCITY = 2.2 FPS

LOCATION	VELOCITY (fps)	ΔT (°F)	DILUTION
a	15.0	15.0	0
b	7.3	7.2	2.1
c	4.6	4.6	3.3
d	4.3	4.3	3.5
e	2.2	4.3	3.5

RIVER VELOCITY = 0.02 FPS

LOCATION	VELOCITY (fps)	ΔT (°F)	DILUTION
a	15.0	15.0	0
b	7.2	7.3	2.1
c	4.7	4.7	3.2
d	4.4	4.4	3.4
e	0.02	4.4	3.4

Figure 3.3-3. *Submerged discharge jet analysis for the Bowline Point Generating Station based on model and field thermal survey results (from LMS 1978:p. 4-31).*

(7.7 F) have been observed (Subsection 3.3.1.1, Table 3.3-1). Temperature elevations of this magnitude, however, would be rare, since the frequency plot of maximum surface temperature rises measured within the thermal plume (Subsection 3.3.1.3, Figure 3.3-2) indicates that a surface temperature rise of 4.2 C (7.5 F) occurs less than 1 percent of the time. Furthermore, the surface area and volume of the plume affected by temperatures of 3.3 C (6 F) or more are extremely small. Surveys conducted at near-maximum plant operating capacity (approximately 93 percent) during high summer ambient conditions (18 August 1975) recorded maximum surface areas and volumes within the 3.3 C (6 F) isotherm of 0.69 acres and 2.99 acre-ft (Subsection 3.3.1.1, Table 3.3-2). These values represent 0.01 percent of the surface area and 0.022 percent of the volume within two tidal excursions of Bowline Point.

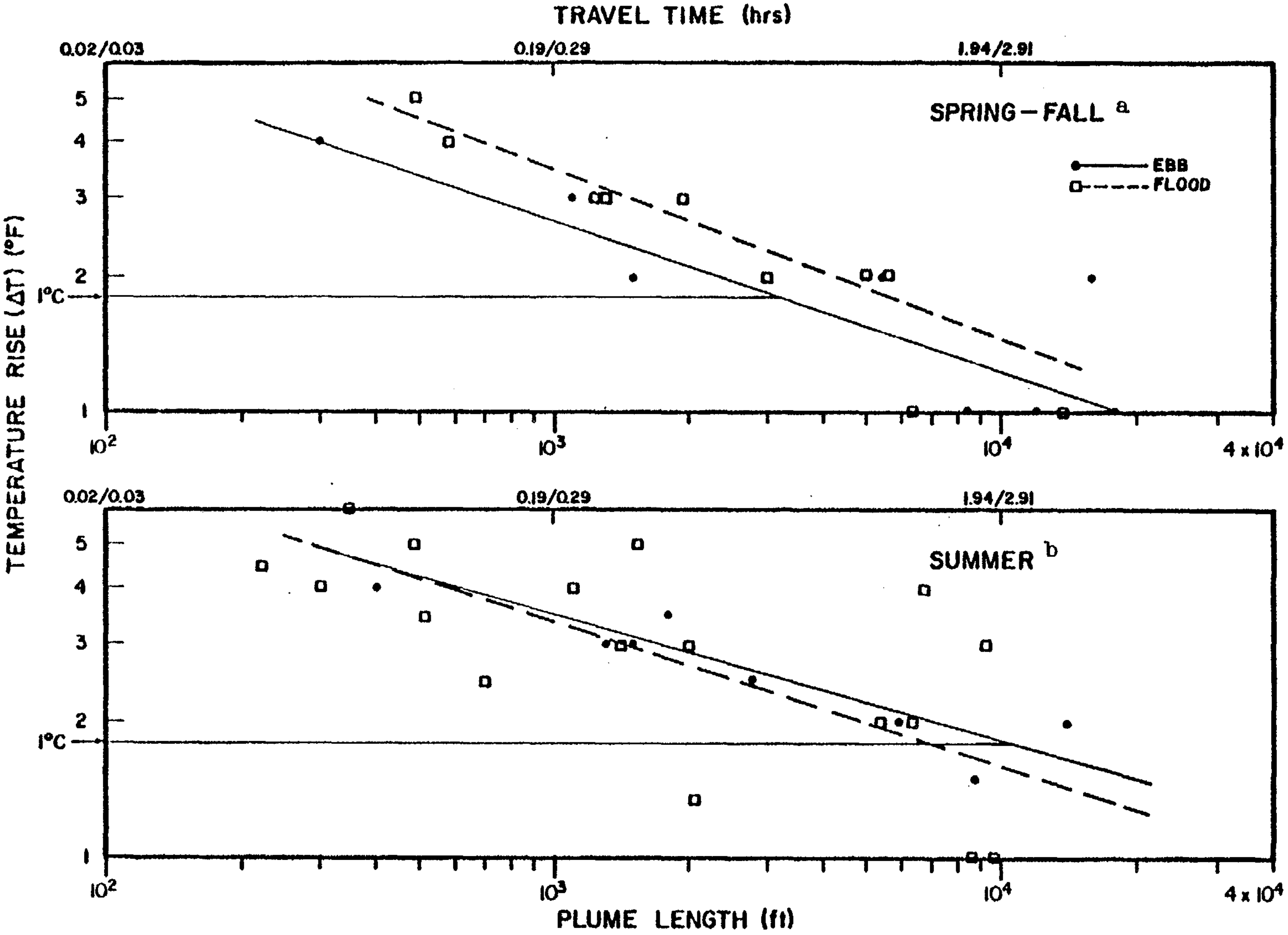
Thus, within 5-10 seconds (20-40 ft) of the diffuser port, the corresponding temperature of the discharge water has been decreased to approximately 2.4-4.3 C (4.3-7.7 F) by rapid dilution. This temperature range is also consistent with the range of maximum temperatures at the surface, since upon reaching a velocity of 4.3-6.0 fps the discharge water floats upwards with little additional dillution taking place. Temperatures within this range that are $\geq$3.3 C (6.0 F), even at high plant loads and warm summer ambient temperatures, affect a minimal percentage of near-field surface area and volume, and temperatures $\geq$4.2 C (7.5 F) occur rarely.

3.3.1.5 Time-Temperature Profile

For this analysis, temperature decay of a water particle from discharge port to 1 C (1.8 F) is assummed to occur within one tidal phase. Although temperature decay may continue for a short time into the next tidal phase, it will be quickly diluted below 1 C (1.8 F). Results of field thermal surveys support this assumption, despite the fact that continuous tracking of the discharge water and/or its temperature decay has not been performed between tidal phases.

A review of field thermal surveys for the Bowline Point vicinity indicates that the longest plume occurs during maximum ebb tide, when the plume extends downriver for some distance (LMS 1978:pp. 6-1 - 6.2). However, surface plumes during flood tide are usually slightly warmer in the near field and cooler in the far field than during ebb tide (thermal maps of the plume for various seasons and tidal phases are presented in LMS 1978:Appendix). Plume length versus temperature rise above ambient for ebb and flood tide, as measured during seven thermal surveys, indicates that the plume length is dependent on seasonal conditions with the longest plume occurring during the summer (Figure 3.3-4). Based on these plume lengths, average ebb and flood current velocities of 1.44 fps and 0.96 fps, respectively, and the discharge velocity-temperature relationships shown in Figure 3.3-3, the maximum time-temperature profile from the discharge port to the 1 C (1.8 F) isotherm during spring-fall and summer conditions was derived (Figure 3.3-5).

This time-temperature profile and the discharge velocity-temperature analysis (Subsection 3.3.1.4) indicate three mixing zones for the discharge water. The first is the rapid initial dilution zone within the first 20-40 ft from the discharge jet in which the temperature is diluted from the condenser-induced temperature rise to approximately 2.4-4.3 C (4.3-7.7 F) above ambient within 5-10 seconds of discharge. In the second zone, the discharge flow is further dissipated with some additional decrease in temperature; this zone occurs within 20-30 minutes of the discharge port. The third zone covers the movement of the plume by tidal currents in which the temperature gradually decreases to ambient.



[a] NOV 1974, APR 1975, and OCT 1975 (see LMS 1978: Appendix).

[b] 2 AUG 1974, 29 AUG 1974, JUN 1975, and AUG 1975 (see LMS 1978: Appendix).

Figure 3.3-4. Length of Bowline Point Generating Station's thermal plume versus temperature rise above ambient during ebb and flood tidal phases (from LMS 1978:p. 6-4).

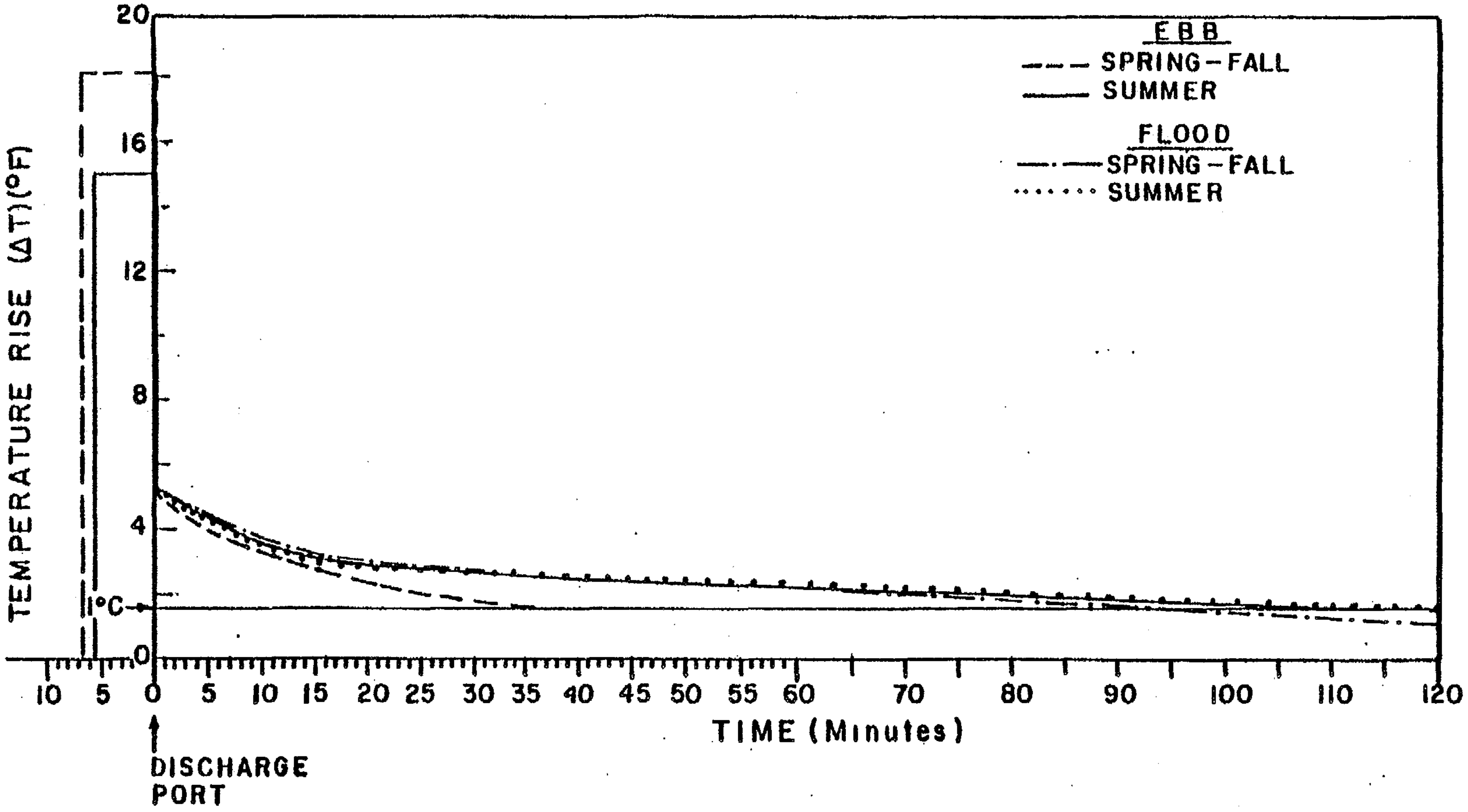


Figure 3.3-5. Bowline Point Generating Station, time-temperature profile from discharge port to 1 C isotherm.

3.3.2 Far-Field Hydrothermal Effects

Far-field hydrothermal effects refer to the residual low-level temperature increases over a large area caused by a thermal discharge after initial mixing in the near-field has occurred. It is in the far field that the majority of the cooling water heat is exchanged into the atmosphere, particularly in the case of submerged diffuser-discharge systems which enhance the mixing of the heated effluent with the river water. Far-field heat is difficult to measure in the field because of the extensive distance over which measurements must be taken, and the variations in river ambient temperatures or natural heat inputs that obscure the distinctions between natural and artificial heat. For this reason, mathematical models are generally used to analyze far-field effects because of the ease with which artificial heat can be added or removed.

In the case of the Bowline Point plant and other generating stations that utilize Hudson River water for once-through cooling, a one-dimensional, multi-segment model (LMS 1978:pp. 4-37 - 4-40) was developed to analyze far-field, steady-state temperature increases caused by individual as well as combined discharge heat input. Based on the results of this model, a river cross-sectional, tidal-average temperature rise of 0.2 C (0.4 F) was predicted to occur at Bowline Point as a result of full-capacity operation of Bowline Point Units 1 and 2. The cross-sectional, tidal-average temperature rise predicted at Bowline Point for the combined discharge from the Bowline Point plant and four other mid-Hudson generating stations (Lovett Units 1-5, Indian Point Units 1-3, Roseton Units 1-2, and Danskammer Point Units 1-4), assuming full-capacity operation for all units, was 0.9 C (1.6 F) (LMS 1978:pp. 5-1 - 5-3).

It should be noted that studies comparing the model predictions with actual observed data (LMS 1974, 1975c) show that the model is conservative, i.e., the model predicts higher temperature rises. In addition, the combined plant far-field temperature effects predicted by the model are based on drought flow conditions and maximum capacity operation for all plants, which represents the worst possible situation.

3.3.3 Effects of Cooling Water System Operation on River Water Chemistry

3.3.3.1 Dissolved Oxygen Levels

As was noted previously (Subsection 3.1.3.3), dissolved oxygen (DO) concentrations within the Hudson River estuary in the vicinity of Bowline Point in recent years (1973-1976) have ranged from approximately 5.0 to 13.5 mg/liter; maximum values occur in winter and early spring, and minimum values in middle to late summer. These concentrations are above the safe levels recommended by the "Report of the Committee on Water Quality Criteria" (FWPCA 1968:p. 70) for maintaining survival, growth, reproduction, and the general well-being and production of aquatic organisms in estuarine environments. As specifically stated:

> Dissolved oxygen concentrations in estuaries and tidal tributaries shall not be less than 4.0 mg/liter at any time or place except in dystrophic waters or where natural conditions cause this value to be depressed.

In order to estimate the effect of the operation of the Bowline Point plant on river DO, a mathematical model (Lawler 1972, 1973) was used to simulate DO losses through the plant's circulating water system. The model was then verified using DO measurements taken at the plant's intake and discharge by LMS (1974, 1975c), and used to predict losses under maximum summer and winter river temperature conditions. The following results were obtained:

1. Based on the mathematical model (verified by field studies), the passage of cooling water through the Bowline Point plant will reduce the DO concentration in the water by approximately 0.90-1.50 mg/liter during the winter or early spring when DO in the river is at its highest level (usually less than 100 percent saturation). A smaller decrease in DO, on the order of 0.02-0.97 mg/liter (based on a plant flow of 316,000 gpm), occurs during the summer.
2. As a result of the loss of DO in the circulating water, DO in the river at Bowline Point is reduced a maximum of about 0.08 mg/liter (0.55 percent loss) during the winter at an average river flow of 24,000 cfs, and by 0.16 mg/liter (1.97 percent loss) in the summer, based on the 7-consecutive-day low river flow of 3,500 cfs.

Based on the varying solubility of oxygen in water at different temperatures and chloride concentrations, elevated temperatures within the 2.2 C (4 F) temperature rise isotherm of the Bowline Point plant's thermal plume would result in an average reduction in river DO of 0.22-0.88 mg/liter, depending on season. Highest reductions would occur during winter and early spring when ambient water temperatures are lowest, salinity is low, and natural DO levels are highest; lowest reductions would occur during summer. The maximum volume of water measured within the 2.2 C (4 F) isotherm of the plume during the field thermal survey conducted on 18 June 1975 (Subsection 3.3.1.1, Table 3.3-2), when the plant was operating at 93.8 percent capacity (two-pumps - throttled operating mode), was 170 acre-ft or 0.12 percent of the river volume within two tidal excursions of Bowline Point. This volume, therefore, represents the maximum volume of river water expected to be affected by such local DO reductions within the 2.2 C (4 F) isotherm.

Thus, DO losses incurred during passage of cooling water through the Bowline Point plant, or as a result of temperature elevations in the river ($\geq$ 2.2 C [4 F]) caused by the plant's thermal discharge, do not appreciably diminish natural DO levels in the receiving water. Greatest reductions (<1.0 mg/liter) would occur during winter and early spring when river DO levels are highest (>10 mg/liter) and would be limited to a small volume of river water within the immediate vicinity of the discharge. These reductions are not expected to cause river DO concentrations to fall below the recommended safe levels for maintaining the well-being and production of the aquatic biota.

3.3.3.2 Chlorination

At the Bowline Point plant, a 15 percent solution of sodium hypochlorite is occasionally added to the cooling water to minimize slime growth in the condensers (for a description of chlorination procedures, see ORU 1977:pp. 2.4-1 - 2.4-3); this is the only chemical added to the cooling water. In the past, when chlorination was performed, the condenser cooling water for each unit was chlorinated separately once each day for 30 minutes during that period when the water temperature of the Hudson River estuary was above 10 C (50 F). This temperature regime usually occurs from late spring through midfall. Because of the low levels of organic growth observed, however, the frequency of chlorination has been reduced to three times a week. Based on this frequency, approximately 115 lb per week of free residual chlorine are discharged into the river during the chlorination period (i.e., when river temperatures are >10 C [50 F]) to achieve concentrations of free residual chlorine at the outlet of the condenser averaging 0.2 mg/liter.

The effects of cooling water chlorination on free residual chlorine concentrations in the receiving water has been studied at both the Bowline Point plant and the Indian Point Generating Station located apporoximately 5 mi upstream. Results of these studies have indicated an initial river chlorine demand of 0.8 mg/liter at an initial laboratory test concentration of 2.5 mg/liter, and therefore a chlorine demand to initial chlorine concentration ratio of 0.32; during other studies, ratios of 0.62 to 0.85 were observed (LMS 1978:pp. 8-2 - 8-4). Based on these river chlorine demand ratios, an initial concentration of 0.2 mg/liter of free residual chlorine at the discharge, and the various dilutions encountered in the plume, the following concentrations of free residual chlorine in the receiving water have been calculated for the Bowline Point plant's discharge:

	Free Residual Chlorine River Demand Ratios (mg/liter)	
Dilution Ratios	0.32	0.85
Initial Minimum = 1.6 (based on max. surface temp.)	0.1075	0.0838
Average Initial = 3.23	0.0425	0.0229
Dilution to 2.2 C (4 F) = 3.75 (based on discharge delta-T = 8.3 C [15 F])	0.0349	0.0173
Dilution to 1.1 C (2 F) = 7.5 (based on discharge delta-T = 8.3 C [15 F])	0.0140	0.0048

Recent investigations have indicated that such low-level concentrations of free residual chlorine are well within safe levels for fish and other aquatic organisms. Liden and Burton (1977) for example, found that residual chlorine concentrations of 0.014-0.062 mg/liter, which were effective for biofouling control in a once-through steam electric power plant located along the Potomac River estuary, were not lethal to juvenile Atlantic menhaden (*Brevoortia tyrannus*) and spot (*Leiostomus xanthurus*) exposed continuously to halogenated discharge water (≃30 C [86 F]) for 19 and 20 days, respectively. Laboratory tests conducted by Brooks and Seegert (1977) further indicate that fish exposed to intermittent chlorination can tolerate substantially higher residual chlorine concentrations. For example, the LC50 for juvenile yellow perch (Perca flavescens) a warm water species, exposed to residual chlorine for a single 30-minute dose at water temperatures varying in 5 C (9 F) increments from 10 to 30 C (50-86 F) ranged from 0.70 mg/liter at 30 C (86 F) to 8.0 mg/liter at 10 C (50 F). For juvenile rainbow trout (Salmo gairdneri), a species which prefers cooler water temperatures, the 30-minute LC50 values were 0.99 and 0.94 mg/liter residual chlorine at test temperatures of 10 and 15 C (50 and 59 F), respectively, and 0.60 and 0.43 mg/liter for two groups of trout tested at 20 C (68 F). For both species, chlorine concentrations resulting in no mortality were approximately one half the LC50 value. Baush and Truchan (1976) similarly found that a variety of warm water fish species were able to survive repeated 30-minute exposures to chlorine levels up to 0.5 mg/liter.

In the experiments conducted by Brooks and Seegert (1977), mortality of the yellow perch and rainbow trout exposed to varying chlorine concentrations for 30 minutes occurred primarily within the first 24 hours after exposure, with an average of 7 percent of the mortality occurring within the second 24 hours. Observations over a period of several weeks indicated that little subsequent mortality occurred and, therefore, little or no delayed mortality would be expected more than 48 hours after treatment.

Results of these studies, and others, indicate that the low-level residual chlorine levels, which occur intermittently in the area of the Bowline Point plant discharge, will not be harmful to fish and other aquatic organisms. It should also be noted that the residual chlorine levels reported above for the discharge plume at Bowline Point are higher than expected, since the calculations upon which these values are based do not take into account decay resulting from ultraviolet light, a factor that may be significant once the plume rises to the surface. In addition, the dilution values used to calculate residual chlorine concentrations in the plume were based on heat dilution ratios for two-unit operation (both units discharging heat) or one-unit operation (with no discharge flow through the second unit). The separate chlorination of each unit while the other unit is discharging unchlorinated water, as is practiced at the Bowline Point plant, should further dilute residual chlorine levels in the river below those values indicated. In view of these considerations, it is concluded that intermittent chlorination of the cooling water at the Bowline Point plant, at the frequency and dosage currently applied, does not result in residual chlorine levels in the receiving water which exceed safe-levels for the maintainance and well-being of the indigenous biological community.

3.4 BIOTHERMAL RELATIONSHIPS

Certain of the results derived in the hydrothermal analyses of the Bowline Point discharge are particularly important to interpretation of biological data presented in Chapters 4 and 5. These include temperature and spatial characteristics of the thermal plume and their compliance with New York State thermal criteria, temperature-velocity relationships of the discharge water, and the maximum time-temperature exposure that planktonic organisms would experience as a result of plume entrainment.

3.4.1 Plume Characteristics and Compliance with New York State Temperature Criteria

The combination of an offshore location and high-velocity diffuser design for the Bowline Point plant's cooling water discharge structure were selected to achieve plume temperature conditions with low potential for adverse effects on aquatic life, as required by the highly protective New York State thermal criteria.

Because of the offshore discharge location, the rapid dilution induced by the diffuser, and the changing location of the plume through each tidal cycle, shallow shoal and shore habitats in the vicinity of the Bowline Point plant are only exposed intermittently to temperature elevations less than 2 C above ambient (Subsection 3.3.1.2, Figure 3.3-1). This amount of temperature change is within the range of naturally occurring channel-to-shore, diel, and day-to-day temperature variations experienced by aquatic life that occur within the Hudson River estuary (Subsection 3.1.3.2).

The river bottom and associated aquatic life (benthos) in the vicinity of the Bowline Point plant thermal discharge are protected in the spring, summer, and fall seasons from temperature elevations greater than 2.2 C (4 F) above ambient because of the 5° angle of the discharge away from the bottom, rapid induced dilution, and the natural buoyancy of the plume (Subsection 3.3.1.4). During cold winter ambient river temperature conditions (<4 C [7.2 F], it is expected that the plume would sink rarely, if at all, because of salinity gradients, temperature, and density differences present in the river in the vicinity of Bowline Point. A survey conducted to specifically evaluate the behavior of the plume under winter conditions (10 January 1973), in fact, indicated that even in the absence of a vertical salinity gradient the plume did not sink but more typically exhibited neutral buoyancy with uniform temperatures extending from surface to bottom, and affecting as much of the bottom as the surface (LMS 1978:p. 4-19 - 4-20).

Analyses of the 2.2 C (4 F) surface temperature rise isotherm, as required to evaluate compliance with New York State thermal criteria, indicate that the area bounded by this isotherm is minimal and is restricted to the deeper open-water portion of the river (Subsection 3.3.1.2, Figure 3.3-1). This open water is inhabited by small nonmotile or weak-swimming plankton and the larger nekton consisting mostly of fish and some invertebrate animals. The maximum percentages of river cross-sectional area and surface width within the 2.2 C (4 F) isotherm, based on field thermal survey measurements, were 5.5 and 7.9 percent, respectively (Subsection 3.3.1.1, Table 3.3-1). Therefore, more than 90 percent of the river cross-section and surface width remain available as safe zones of passage according to the 2.2 C (4 F) criterion, even during plant operation approaching maximum capacity (93-98 percent)* (Subsection 3.3.1.1, Table 3.3-1). It is inferred by the New York State thermal criteria that the aquatic community will be protected if no less than 50 percent of the river cross section and 34 percent of the river surface width remain available as safe zones of passage (i.e., are characterized by temperatures no more than 2.2 C [4 F] above ambient).

The New York State thermal criteria state that:

> From July through September, if the water temperature at the surface of an estuary before the addition of heat of artificial origin is more than 83 F, an increase in temperature not to exceed 1.5 Fahrenheit degrees at any point of the estuarine passageway...may be permitted.

Temperature measurements taken daily, or several times a day, at USGS monitoring stations located at MP 43 near Bowline Point during October 1959 to February 1969 indicate a maximum ambient river temperature of 27.2 C (81 F) (Subsection 3.1.3.2, Table 3.1-4). These data represent the most extensive ambient temperature records available for the Bowline Point vicinity and, in fact, may be warmer than the expected river-wide ambient owing to the likelihood of increased solar heating and reduced mixing at the specific monitoring sites (Subsection 3.1.3.2). Based on this 10-year record, ambient river temperatures of 28.3 C (83 F) (before the addition of artificial heat) have not occurred and are not expected to occur in the vicinity of Bowline Point. Thus, the 0.8 C (1.5 F) temperature increase limit is not applicable to the Bowline Point plant.

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* The more conservative mathematical model predictions (Subsection 3.3.1.3, Table 3.3-4) indicated a maximum river cross-sectional area and surface width bounded by the 2.2 C (4 F) isotherm of 7 percent and 31 percent, respectively (at maximum plant capacity). Based on these results, 93 and 69 percent of the river cross section and surface width, respectively, remain available for safe passage of organisms according to the 2.2 C (4 F) criterion.

3.4.2 Discharge Velocity - Temperature Relationships

Fish would not be exposed to discharge temperatures greater than 4.3 C (7.7 F) above ambient for extended periods of time because of the high velocities in the immediate vicinity of the discharge (Subsection 3.3.1.4, Figure 3.3-3). Critical swim speed data (Table 3.4-1) indicate that discharge velocities greater than 4 fps are unlikely to be continuously negotiated by most fishes occurring near Bowline Point. As indicated in Subsection 3.3.1.4, the velocity of the discharge flow decreases from about 15 fps to 4.3-6.0 fps within approximately 40 ft or less (5-10 seconds) of the diffuser port (Figure 3.4-1); the temperature of the discharge water upon reaching velocities less than 4.3-6.0 fps is correspondingly reduced from the maximum induced condenser temperature rise to 2.4-4.3 C (4.3-7.7 F) above ambient.

Thus, the 4.3 C* (7.7 F) isotherm represents the maximum discharge temperature increase above ambient at which fish can maintain themselves for a sufficient time to acclimate to it, or for potential thermal effects to occur. During the majority of time, this maximum habitable isotherm is lower since the frequency plot of maximum surface temperature rises measured within the thermal plume (Subsection 3.3.1.3, Figure 3.3-2) indicates that surface temperature rises of ≥4.2 C (7.5 F) occur less than 1 percent of the time.

In addition to the fact that temperatures ≥4.2 C (7.5 F) occur rarely, the area of the plume that would be affected by such temperature elevations is extremely small and would encompass a maximum surface area and volume of less

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* This temperature is the highest maximum surface temperature rise recorded during field surveys of the Bowline Point plant's thermal plume (Subsection 3.3.1.1, Table 3.3.1); it was recorded on 18 June 1975 at a plant operating capacity of 93.8 percent and a river ambient temperature of 23.1 C (73.5 F).

TABLE 3.4-1 CRITICAL SWIMMING SPEEDS AT VARIOUS TEMPERATURES REPORTED FOR SELECTED HUDSON RIVER FISHES.

Species	Acclimation Temperature Range (C)	Fish Length Range (TL in mm)	Critical Swim Speed Range(a) (ft/sec)	References
White Perch	5.0-27.0	70-221	0.76-3.76	Meldrim et al. (1974:95-97)(b)
				Terpin et al. (1977:51)(c)
Atlantic silversides	5.0-26.0	61-123	0.26-2.46	Wyllie et al. (1976:50-51)(c)
				Meldrim et al. (1974:101-102)(b)
Striped bass	9.0-26.0	107-224	0.75-4.01	Meldrim et al. (1974:111)(b)
				Terpin et al. (1977:51)(c)
Weakfish	10.0-25.0	100-165	1.16-2.11	Terpin et al. (1977:52)(c)
Bluefish	20.0-26.0	80-191	1.55-3.22	Wyllie et al. (1976:52)(c)
				Terpin et al. (1977:49)(c)
Bay anchovy	5.0-25.0	53-95	0.40-1.38	Wyllie et al. (1976:47)(c)
				Terpin et al. (1977:49)(c)

(a) Critical swim speeds were determined as the highest velocity at which a fish could maintain itself for a 10-minute test period as velocities were increased in increments of 0.1 ft/sec every 10 minutes from an initial velocity of 0.1-0.5 ft/sec until the fish was unable to swim against the current. Critical swim speeds were calculated according to Brett (1964).

(b) Test salinities range from 0.01 to 12.0 ppt.

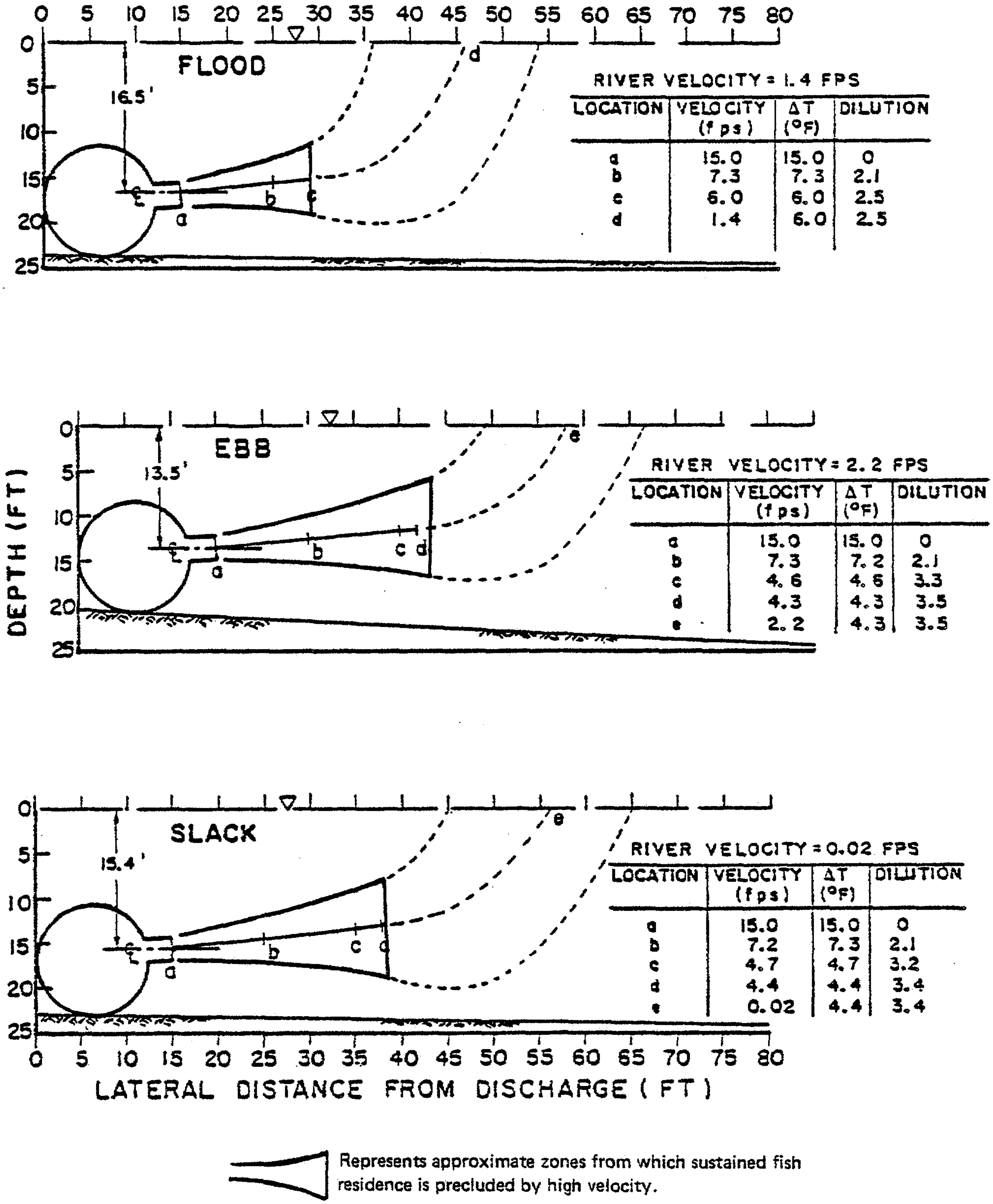
(c) Test salinities range from 23.5 to 28.0 ppt.

TABLE 3.4-1 (CONT)

Species	Acclimation Temperature Range (C)	Fish Length Range (TL in mm)	Critical Swim Speed Range(a) (ft/sec)	References
Atlantic menhaden	5.0-25.0	74-180	1.10-3.86	Wyllie et al. (1976:46-47)(b) Terpin et al. (1977:48)(b)
Alewife	5.0-25.0	90-141	0.87-2.77	Wyllie et al. (1976:46)(b) Terpin et al. (1977:48)(b)
Blueback herring	10.0-21.0	83-110	0.53-1.3	Wyllie et al. (1976:46)(b) Terpin et al. (1977:48)(b)

(a) Critical swim speeds were determined as the highest velocity at which a fish could maintain itself for a 10-minute test period as velocities were increased in increments of 0.1 ft/sec every 10 minutes from an initial velocity of 0.1-0.5 ft/sec until the fish was unable to swim against the current. Critical swim speeds were calculated according to Brett (1964).

(b) Test salinities range from 23.5 to 28.0 ppt.



RIVER VELOCITY = 1.4 FPS

LOCATION	VELOCITY (fps)	ΔT (°F)	DILUTION
a	15.0	15.0	0
b	7.3	7.3	2.1
c	6.0	6.0	2.5
d	1.4	6.0	2.5

RIVER VELOCITY = 2.2 FPS

LOCATION	VELOCITY (fps)	ΔT (°F)	DILUTION
a	15.0	15.0	0
b	7.3	7.2	2.1
c	4.6	4.6	3.3
d	4.3	4.3	3.5
e	2.2	4.3	3.5

RIVER VELOCITY = 0.02 FPS

LOCATION	VELOCITY (fps)	ΔT (°F)	DILUTION
a	15.0	15.0	0
b	7.2	7.3	2.1
c	4.7	4.7	3.2
d	4.4	4.4	3.4
e	0.02	4.4	3.4

Represents approximate zones from which sustained fish residence is precluded by high velocity.

Figure 3.4-1. Jet analysis of Bowline Point Generating Station discharge showing high-velocity zones excluded to fish.

than 0.7 acres and 2.99 acre-ft, respectively, even during periods of high capacity plant operation (93 percent) and warm summer ambient temperature conditions (Table 3.3-2). The occurrence of fish within the warmer portion of the plume (>4.3 C [7.7 F]) that occupies the area within 20-40 ft of the diffuser ports is precluded by discharge velocities in excess of 4 fps and, thus, the potential for lethal stress owing to heat or cold shock is virtually eliminated. For this reason, most of the predictive evaluations of potential effects from the Bowline Point plant's thermal discharge on juvenile and adult life stages of representative important species (RIS) presented in Chapter 5 will concentrate on the effects of plume temperatures ≤4.3 C (7.7 F) above ambient river temperatures.

3.4.3 Time-Temperature Exposure

Whether aquatic organisms are adversely affected by temperatures in excess of specific ambient temperatures depends on both the duration of exposure and amplitude of the temperature rise (time-temperature exposure) relative to the temperature requirements and tolerance of the species or life stage of a species. The time-temperature exposure that planktonic organisms experience as they pass through the thermal plume from the Bowline Point plant depends on where they enter and leave the plume. Profiles of maximum time-temperature exposures that organisms would experience at various tidal conditions if they were entrained immediately at the point of discharge and continued along the centerline of the plume to the 1 C (1.8 F) isotherm are shown in Figure 3.3.5 (Subsection 3.3.1.5). The almost instantaneous (5-10 seconds) reduction in plume temperature to within 2.4-4.3 C (4.3-7.7 F) of ambient greatly reduces the potential for adverse stress (heat shock). About 2 hours would be required for passively drifting organisms in the centerline of the plume to be carried from the 2.4-4.3 C (4.3-7.7 F) isotherm to the 1 C (1.8 F) isotherm, during which time they would be exposed to gradually decreasing water temperatures. Organisms entrained along the edge of the plume would experience a minimal exposure to elevated temperatures of only a few seconds and would be immediately mixed with ambient river water (LMS 1978:p. 6-3).

REFERENCES: CHAPTER 3

Basch, R. E., and J. D. Truchan. 1976. Toxicity of chlorinated power plant cooling waters to fish. U.S. Environ. Prot. Agency, Ecol. Res. Ser. No. R-800700, Duluth, Minn. 105 pp.

Brett, J. R. 1964. Respiratory metabolism and swimming performance of young sockeye salmon. Jour. Fish. Res. Bd. Can. 21(5):1183-1236.

Brooks, A. S., and G. L. Seegert. 1977. The effects of intermittent chlorination on rainbow trout and yellow perch. Trans. Am. Fish. Soc. 106(3):278-286.

Consolidated Edison Company of New York, Inc. (Con Edison). 1977. Indian Point Unit No. 2, Indian Point Unit No. 3, near-field effects of once-through cooling system operation on Hudson River biota.

Darmer, K. I. 1969. Hydrological characteristics of the Hudson River Estuary. Pages 40-55 In Hudson River Ecology, G. P. Howell and G. J. Lauer (Eds.). N.Y. State Department Environmental Conservation.

Federal Water Pollution Control Administration (FWPCA). 1968. Report of the Committee on Water Quality Criteria. U.S. Government Printing Office, Washington, D.C. 234 pp.

Lawler, J. P. 1972. Testimony of John P. Lawler, Ph.D., Quirk, Lawler & Matusky Engineers, on the effect of Indian Point Units 1 and 2 operation on Hudson River dissolved oxygen concentrations. Testimony before the United States Atomic Energy Commission. Docket No. 50-247. 13 November 1972.

Lawler, J. P. 1973. Cumulative effects of Bowline Point, Roseton and Indian Point generating stations on the Hudson River. Testimony before the U.S. Atomic Energy Commission. Docket No. 50-247. 30 March 1973.

Lawler, Matusky & Skelly Engineers (LMS). 1974. 1973 Hudson River aquatic ecology studies - Bowline Point and Lovett Generating Stations. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers (LMS). 1975a. Thermal surveys at the Bowline Point and Lovett Generating Stations. (August) Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers (LMS). 1975b. Thermal surveys of the Bowline Point and Lovett Generating Stations. (October) Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers (LMS). 1975c. 1974 Hudson River aquatic ecology studies - Bowline Point and Lovett Generating Stations. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers (LMS). 1976a. Bowline and Lovett April and June thermal survey compliance. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers (LMS). 1976b. 1975 Hudson River aquatic ecology studies - Bowline Point and Lovett Generating Stations. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers (LMS). 1977. 1976 Hudson River aquatic ecology studies - Bowline Point Generating Station, Volume I. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers (LMS). 1978. Bowline Point Generating Station hydrothermal analysis. Prepared for Orange and Rockland Utilities, Inc.

Liden, L. H., and D. T. Burton. 1977. Survival of juvenile Atlantic menhaden (Brevoortia tyrannus) and spot (Leiostomus xanthurus) exposed to bromine chloride-and chlorine-treated estuarine waters. J. Environ. Sci. Health, A12(8):375-388.

McFadden, J. T. 1977. Influences of Indian Point Unit 2 and other steam electric generating plants on the Hudson River estuary, with emphasis on striped bass and other fish populations. Submitted to Consolidated Edison Company of New York, Inc.

Meldrim, J. W., J. J. Gift, and B. R. Petrosky. 1974. The effect of temperature and chemical pollutants on the behavior of several estuarine organisms. Ichthyological Associates, Inc. Ithaca, N.Y. Bulletin No. 11.

Orange and Rockland Utilities, Inc. (ORU). 1977. Bowline Point Generating Station near-field effects of once-through cooling system operation on Hudson River biota

Quirk, Lawler, & Matusky Engineers and Oceanographic Analysts, Inc. 1971. Environmental effects of Bowline Point Generating Station on Hudson River: Ecological Studies related to the proposed generating station at Bowline Point, N.Y. Prepared for Orange and Rockland Utilities, Inc. and Consolidated Edison Company of New York, Inc.

Robideau, R. F. 1972. The discharge of submerged buoyant jets into water of finite depth. General Dynamics Electric Boat Div. Groton, Conn. U440-72-121:860 (PB 214-475).

Terpin, K. M., M. C. Wyllie, and E. R. Holmstrom. 1977. Temperature preference, avoidance, shock and swim speed studies with marine and estuarine organisms from New Jersey. Report for the period January-December 1976. Prepared by Ichthyological Associates, Inc. Bulletin No. 17. Public Service Electric and Gas Co., Newark, N. J.

Texas Instruments, Inc. (TI). 1976. A synthesis of available data pertaining to major physicochemical variables within the Hudson River estuary emphasizing the period from 1972 through 1975. Prepared for Consolidated Edison Company of New York, Inc.

United States Environmental Protection Agency (EPA). 1974. 316(a) Technical Guide -- Thermal Discharges (Draft). Water Planning Division, Office of Water and Hazardous Materials. Washington, D.C. 187 pp.

United States Environmental Protection Agency (EPA). 1976. Quality Criteria for Water (Prepublication copy). Washington, D.C. 501 pp.

Wyllie, M. C., E. R. Holmstrom, and R. K. Wallace. 1976. Temperature preference, avoidance, shock, and swim speed studies with marine and estuarine organisms from New Jersey. Report for the period January-December 1975. Prepared by Ichthyological Associates, Inc. Bulletin No. 15. Public Service Electric and Gas Co.

Chapter 4

BIOTIC CATEGORY RATIONALES

CHAPTER 4: BIOTIC CATEGORY RATIONALES

4.1 INTRODUCTION

The aquatic community within the Hudson River estuary in the vicinity of the Bowline Point Generating Station includes species characteristic of both fresh and marine waters, as well as true estuarine forms. The species are distributed along a salinity gradient that gradually decreases from the mouth of the estuary at New York Harbor to occasionally as far upstream as the Poughkeepsie area (MP 75); permanent freshwater generally characterizes the estuary above this point. As a result, the Hudson River estuary includes more species than are found within the biotic communities of any one geographical area of the lower river (McFadden 1977:p. 2.59).

The primary energy input at the base of the aquatic food web of the Hudson River estuary (Figure 4.1-1) is detrital material originating from watershed terrestrial and pollutional inputs. Primary producers include phytoplankton, periphytic algae, and aquatic vascular plants; however the estuary is turbid, and shallow light penetration is a major factor limiting plant growth. Consequently, photosynthesis is generally restricted to a shallow surface zone (the upper 3-6 ft), and vascular plants are restricted to marginal nearshore areas generally extending less than 100 yds from shore. Phytoplankton (small, floating aquatic plants), like detritus, serve as a direct source of food for some planktonic and benthic invertebrates and fish. Submergent and emergent aquatic plants are also consumed directly by certain aquatic organisms but probably make their greatest contribution to the food web as a detrital component when they die and decompose. They additionally provide habitat for aquatic invertebrates and are a source of protection for juvenile fish.

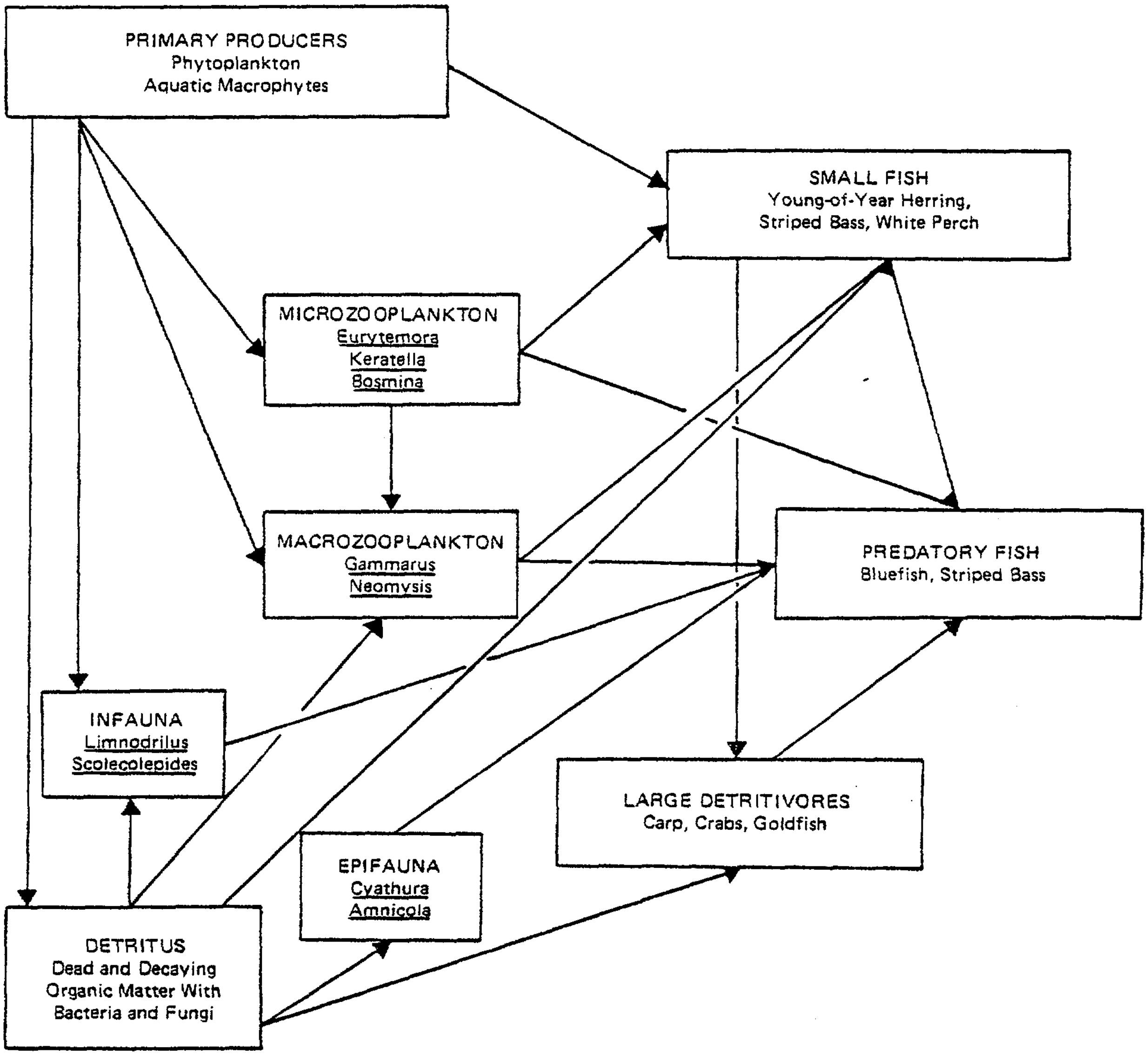


Figure 4.1-1. Diagrammatic food web involving various trophic levels of the Hudson River aquatic community (adapted from McFadden 1977: p. 4.11).

Zooplankton (small invertebrates which occur within the water column) and benthic invertebrates (those found in or on bottom sediments) serve as a middle link in the transfer of energy and materials through the Hudson River food web. These organisms feed on both algae and detrital particles and subsequently provide food for other aquatic invertebrates and higher trophic levels such as fish. Fish, in turn, may be consumed by other fish, or still higher trophic levels (e.g., aquatic birds, mammals, and man). Various species and life stages of fish represent both primary and secondary consumers.

Information provided in this chapter assesses the influence of elevated temperatures caused by the Bowline Point Generating Station's cooling water discharge upon major groups of aquatic organisms (i.e., phytoplankton, zooplankton, macroinvertebrates, habitat formers, fish, and other vertebrate wildlife) that inhabit the Hudson River estuary. Evidence based primarily on nonpredictive near- and far-field, pre- and post-operational field surveys, as well as some data from laboratory and plant thermal tolerance studies (i.e., for biotic categories for which no RIS have been designated), is presented to address specific evaluation criteria listed the Subsection 1.3.3. Much of the information presented herein has been synthesized from "Bowline Point Generating Station Near-Field Effects of Once-Through Cooling System Operation on Hudson River Biota" (ORU 1977). This information has application to the assessment of the combined influence of the entire cooling water system (i.e., discharge as well as intake effects) upon specific biotic categories in light of all other sources of stress which may exist within the system.

4.2 PHYTOPLANKTON

4.2.1 Evaluation Criteria

This section examines nonpredictive evidence, based on field investigations conducted since 1970, to determine whether near- or far-field changes have occurred in the abundance, distribution, or community structure of phytoplankton which can be attributed to the operation of the Bowline Point plant. In addition, some thermal tolerance data is included to provide a predictive assessment of possible effects of the plant's cooling water discharge on the phytoplankton community. The information presented is used to address the following evaluation criteria suggested in the 1 May 1977 draft of the EPA 316(a) Technical Guidance Manual (EPA 1977:p. 18):

1. A shift towards nuisance species of phytoplankton is not likely to occur.
2. There is little likelihood that the discharge will alter the indigenous community from a detrital to a phytoplankton based system.
3. Appreciable harm to the balanced indigenous community is not likely to occur as a result of phytoplankton community changes caused by the heated discharge.

In the Hudson River estuary, as in most large river and estuarine environments, detritus, not phytoplankton, forms the base of the aquatic food web and provides primary input to the energy budget. McFadden (1977:pp. 3.12 - 3.14) reported that approximately 99 percent of the system's energy budget is supplied by watershed terrestrial and pollutional inputs, while only about 0.24 percent is provided by phytoplankton (Table 4.2-1). As stated in EPA (1977: pp. 18-19):

> Areas of low potential impact for phytoplankton are defined as open ocean areas or systems in which phytoplankton is not the food chain base. Eco-

TABLE 4.2-1 ENERGY INPUTS INTO HUDSON RIVER*

Source	kcal yr^{-1} x 10^9	Percent of Total
Benthic plants	40	0.05
Primary Production		
Phytoplankton	200	0.24
Upstream watershed	620	0.76
Lower watershed	80,000	97.61
Human effluents	1,100	1.34
Marine	0.17	<0.001
Total	81,960.17	100.0

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* Adapted from McFadden 1977:p. 3.13.

> systems in which the food web is based on detrital material, e.g.,...most rivers and streams are in this category.

Therefore, in accordance with EPA's definition, the Hudson River estuary should be considered an area of low potential impact to phytoplankton.

4.2.2 Rationale

The thermal discharge from the Bowline Point plant has negligible impact on the Hudson River phytoplankton populations both in the far-field study area and within the thermal plume.

The lack of consistent differences, local depressions, or shifts in density or community composition between plume, near-field, and far-field areas indicate that thermal additions from the Bowline Point plant have not altered the indigenous phytoplankton community of the Hudson River estuary. Phytoplankton abundance has remained relatively stable since 1971 with seasonal fluctuations in abundance and species composition characteristic of temperate zone aquatic systems. The seasonal increase in the blue-green algae population (which when present in great abundance has created a nuisance in other water bodies) has been characteristic of both pre- and post-operational years during the period of summer ambient river temperature. The magnitude and duration of the peak in blue-green algae abundance have shown no trends above typical year-to-year variability.

Based on condenser entrainment studies, laboratory thermal tolerance experiments, the rapid dilution of heat in the discharge area, and the rapid recovery and regeneration rates of algal populations, alteration of the rate of primary production in the thermal plume is not expected beyond the immediate vicinity of the discharge diffuser. Laboratory and intake-discharge survival studies have indicated that reductions in primary productivity in excess of 10-20 percent are not expected until discharge temperatures reach 38 C (100.4 F), a temperature exceeding the maximum discharge temperatures at Bowline Point. Below 38 C (100.4 F) no consistent enhancements or depressions of primary productivity are expected.

Thus, pre- and post-operational, as well as near- and far-field studies of phytoplankton abundance, distribution, and species composition in the vicinity of the Bowline Point plant, have demonstrated that the plant's thermal discharge has not caused prior appreciable harm to this community. Predictive thermal effects studies and hydrothermal analyses of the plume further indicate that heated water discharged by the plant is not expected to alter the indigenous phytoplankton community or cause any change in the energy budget of the Hudson River estuary.

4.2.3 Supportive Information

4.2.3.1 Distribution, Abundance, and Community Structure

Long-river seasonal trends in phytoplankton density and community structure were examined during 1973 and 1974 (Storm and Heffner 1976:pp. 24-26). Phytoplankton density ranged from 10^5 to 10^7 cells per liter, and typically fluctuated within one order of magnitude for the whole estuary during each season examined. Similar long-river density trends were observed during each period examined (i.e., September 1973, and May, August, and October 1974). Densities generally increased from low levels just below Albany (MP 130-140), to a peak near Esopus Meadows (MP 90), and then decreased downriver to about Indian Point (MP 42). A second density peak usually occurred in the Haverstraw Bay area (MP 30-39) where the euphotic zone is increased because of changes in the hydrology and physicochemical characteristics of the river in this area (ORU 1977:p. 6.3-2). This second peak in the vicinity of Haverstraw Bay has also been documented by Boyce Thompson Institute (1973:Section C, p. 5).

The composition of the phytoplankton community in the Hudson River estuary, as indicated by Storm and Heffner (1976), varies seasonally in a manner typical of temperate waters (Figure 4.2-1). During spring, diatoms (Bacillariophyceae) and green algae (Chlorophyta) are the major components throughout the river constituting about 80 and 20 percent of the community, respectively. In summer, green algae is most abundant, with diatoms next in importance. Blue-green algae (Cyanophyta), which constitute about 20 percent of the community at Albany during the summer, decrease in importance downstream and are absent below MP 30. In late September, diatoms and green algae dominate the community above MP 110 and below MP 30; between these points blue-green and green algae are dominant. In late October, the community structure is similar to that found in the spring; diatoms and green algae dominate the community. During midfall, blue-green algae are present only in the lower portions of the river below MP 80 and constitute less than 20 percent of the community in that area.

These trends in density and community structure suggest that several environmental factors affect algal distributions--freshwater flow, salinity, light, and temperature. The freshwater flow, to a considerable extent, determines the long-river community composition above the salt front, since as a result of downstream transport, the composition at any point is usually reflective of the community structure upstream. Downstream transport of algae indicated by the August-October shift in blue-green algae (ORU 1977:Section 6.3) is further documented in QLM (1966 supplement), and Heffner (1974:p. 14). The influx of saline water in the lower portion of the river, which is controlled partially

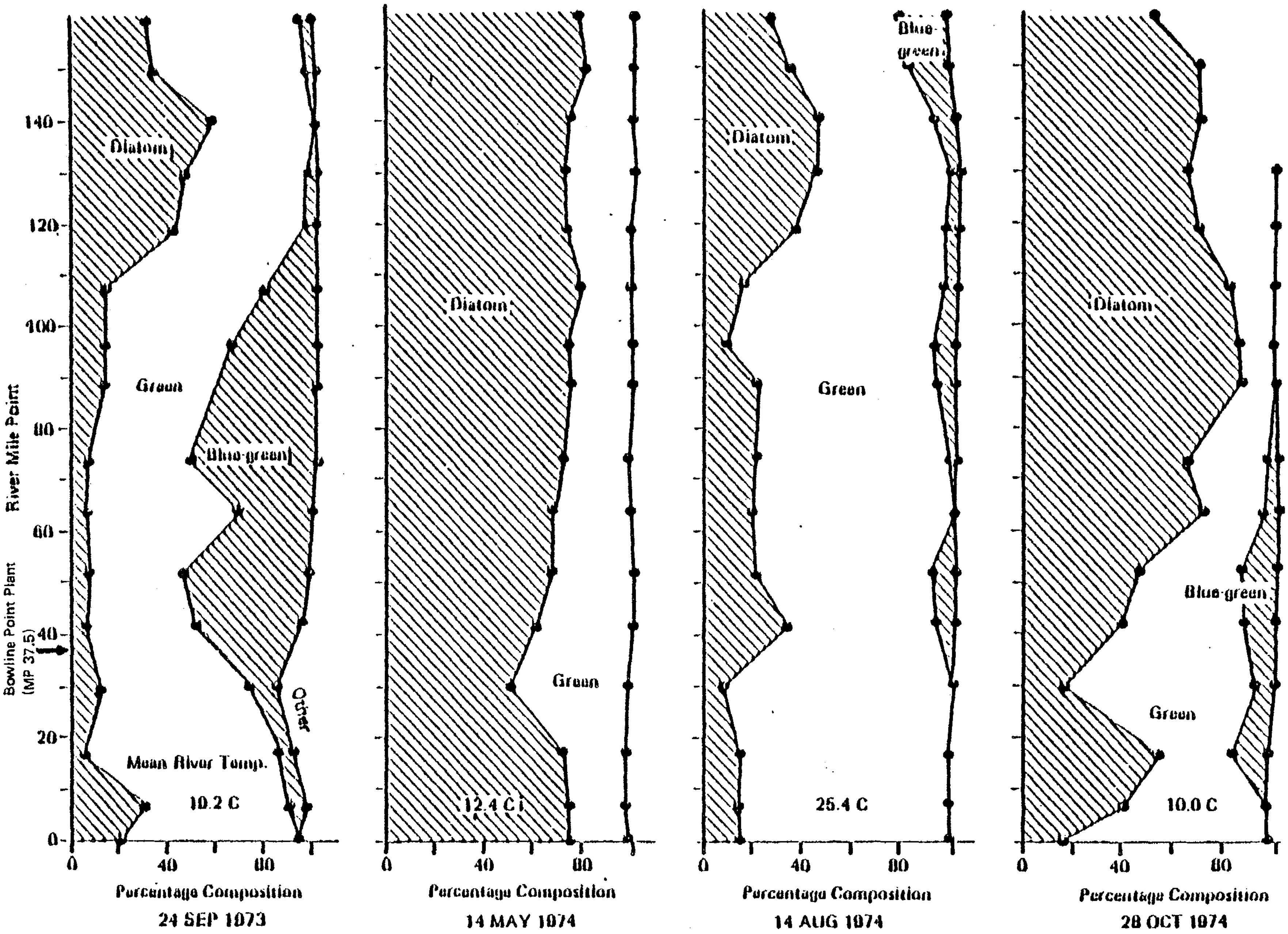


Figure 4.2-1. Phytoplankton community structure in the Hudson River during 1973 and 1974 (adapted from Storm and Heffner 1976).

by freshwater flow, is accompanied by an influx of marine algal species (Boyce Thompson Institute 1973:Section C, p. 8). Changes in abundance and community structure (Figure 4.2-1) between MP 30 and 45 are indicative of the highly variable nature of the aquatic environment resulting from the intrusion and mixing of the saline water mass in the area (TI 1976b:p. IV-2). The influence of light and temperature are interrelated since both vary in similar seasonal patterns. Green and blue-green algae are favored in the warmer months when light levels are generally maximum. Diatoms, on the other hand, are favored in the cooler months when light is reduced from maximum summer levels.

No local depressions in long-river phytoplankton abundance or changes in community structure were apparent in the vicinity of the Bowline Point plant's heated discharge. Most of the 200 taxa identified in the phytoplankton community in the vicinity of the Bowline Point plant from 1971 through 1976 were representative of the green algae, blue-green algae, and diatoms (ORU 1977: pp. 6.1-7 - 6.1-17). Although the number of taxa identified increased each year due to changes in laboratory procedure and sample design, the pattern of seasonal succession among these three major groups remained similar between years (Figure 4.2-2) and was consistent with long-river patterns.

Annual abundance in the vicinity of the Bowline Point plant is bimodal with spring and fall peaks (Figure 4.2-3). Composition during these peak abundance periods is dominated by diatoms and green algae (Figure 4.2-4); during the summer abundance decreases and the community is dominated by the more heat-tolerant green and blue-green algae. Annual variation in the time and magnitude of abundance peaks and relative abundance is influenced by annual variation in temperature and conductivity. Highly variable conductivity in the Bowline Point area in 1976 may have influenced the erratic shifts in rela-

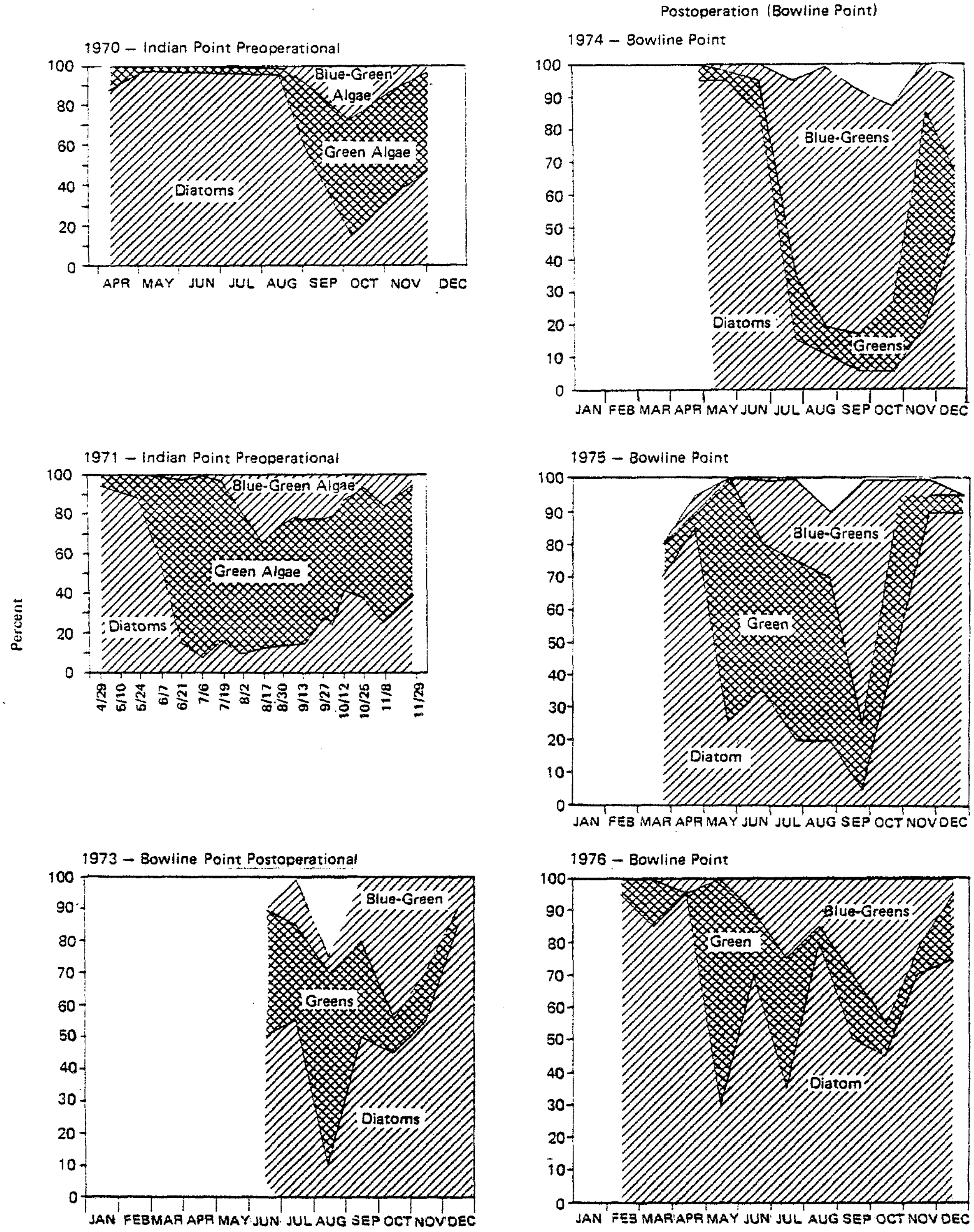


Figure 4.2-2. Phytoplankton community percent composition during pre- (1970 and 1971) and post-operational (1973-1976) period for the Bowline Point plant (1970 and 1971 adapted from Lauer et al. 1974: p. 52; 1973-1976 adapted from ORU 1977: pp. 6.1-21, 6.1-22, and 6.1-25).

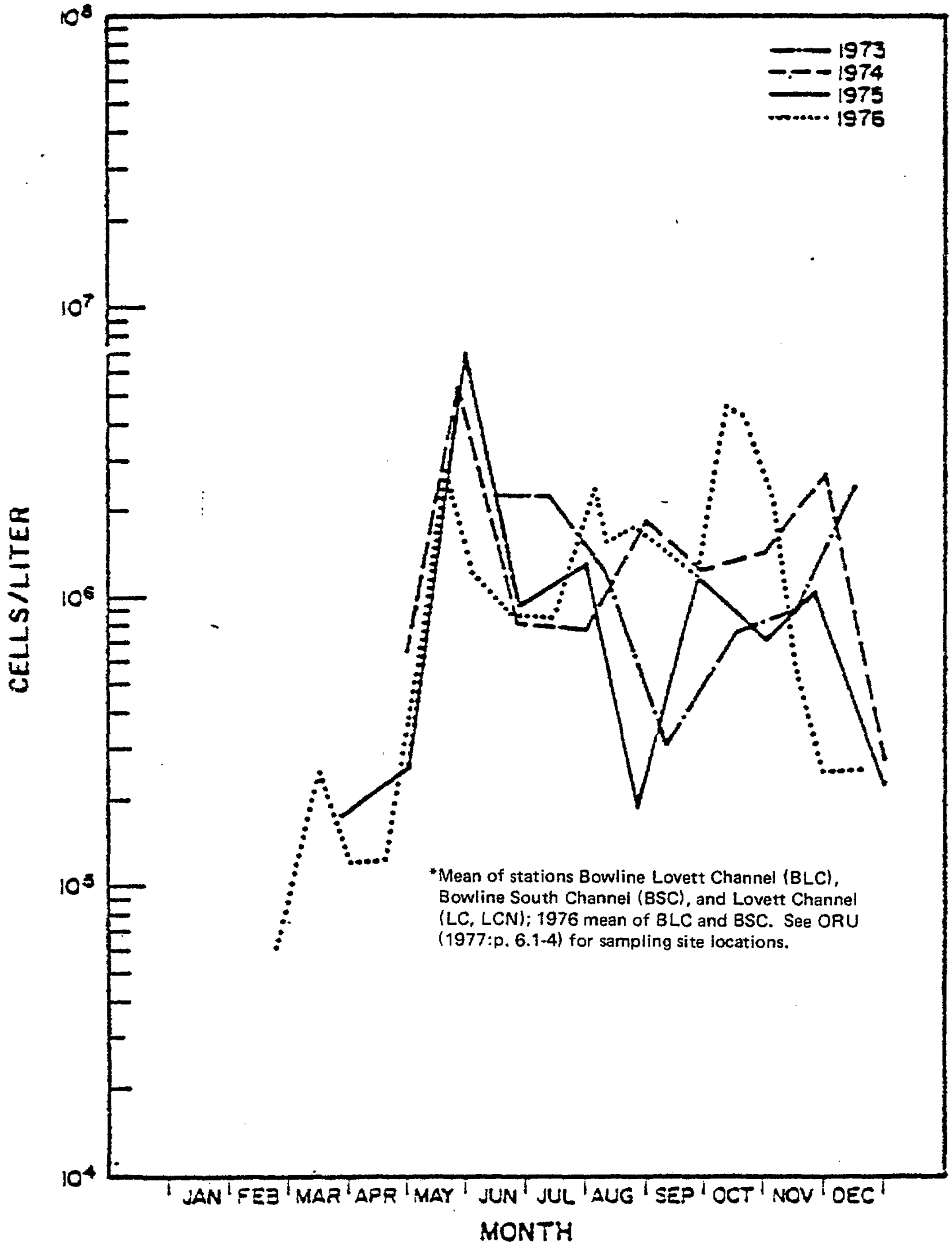


Figure 4.2-3. **Monthly mean* abundance of total whole water phytoplankton collected in the vicinity of the Bowline Point plant—1973-1976 (ORU 1977:p. 6.1-19).**

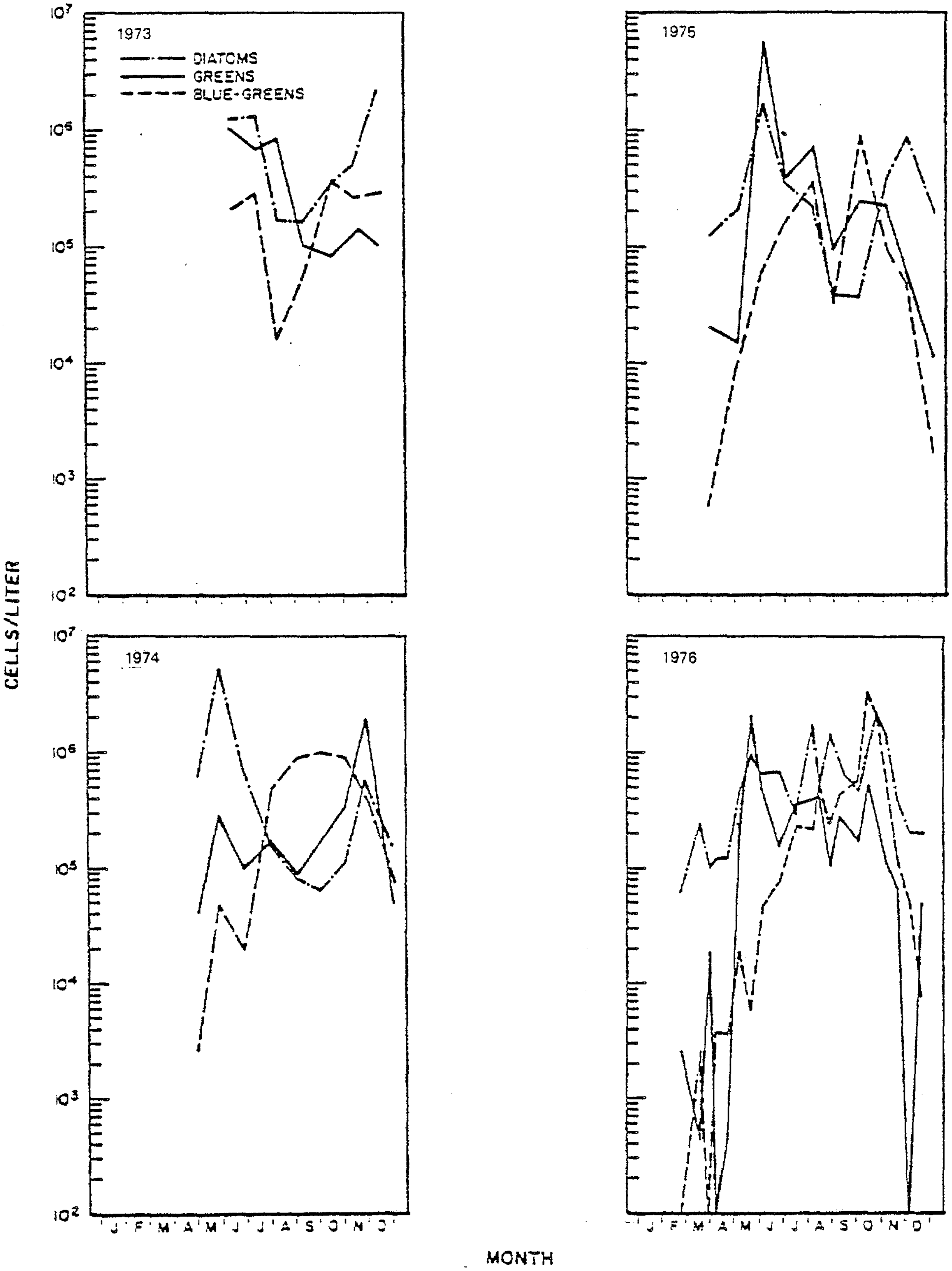


Figure 4.2-4. Abundance of major phytoplankton in non-thermally affected areas near the Bowline Point plant (adapted from ORU 1977: Figures 6.1-3, 6.1-4, 6.1-6, and 6.1-8).

tive abundance of the three dominant phytoplankton groups. Although comparison of phytoplankton abundance demonstrated spatial variability in the vicinity of the Bowline Point plant, no consistent differences were apparent between the plume and thermally unaffected areas (ORU 1977:p. 6.1-54). Seasonal abundance and relative abundance patterns were similar during the post-operational period from 1973 through 1976. In general, seasonal variability was much greater than spatial variability and no plume or near-field effects of once-through cooling at the Bowline Point plant were discerned.

No major spatial shifts in abundance or changes in species composition of the most abundant taxa could be related to the discharge of heated water from the Bowline Point plant. ORU (1977:pp. 6.1-34 - 6.1-51) identified the five most abundant species for each sample collected during the 4-year period from 1973 through 1976 and noted that the dominant species during each sampling period were present at all or most stations and were representative of the major phytoplankton groups expected at that time. No differences were evident in the spatial distribution of the most abundant species within years, and while differences between years were apparent, eleven genera were dominant and common to all 4 years (1973-1976). All but one of the eleven dominant genera were indicative of the high organic loads in the Hudson River.

Blue-green algal abundance and distribution have not changed significantly due to thermal discharges from the Bowline Point plant. Blue-green algae--generally considered nuisance species and associated with high phytoplankton concentrations in eutrophic conditions, planktonic fouling of drinking water, and occasional toxicity in high abundance--were a dominant component of the community from mid-August through late October in all four postoperational years. Phytoplankton collections from the Indian Point near-field area (MP 39-43) indicate that the same pattern existed in 1970 and 1971 prior to the operation of the Bowline Point plant (Figure 4.2-2). Since no near-field effects were found in this area due to operation of Indian Point Unit I (Con Edison 1977: p. 6.4), these data are considered to be representative of the preoperational phytoplankton community in the vicinity of the nearby Bowline Point plant. The increase in blue-green algal abundance in the Hudson River estuary is a seasonal trend associated with maximum summer temperatures and also indicative of high organic loading. In the vicinity of the Bowline Point plant, this trend has not been found to be substantially different during pre- and post-operational years or between plume, near-field, or far-field study areas. Seasonal patterns therefore indicate that the thermal discharge from the Bowline Point plant has not increased the seasonal duration or abundance of blue-green algae.

There is no evidence to indicate that the heated water discharged by the Bowline Point plant has altered the phytoplankton community structure within the near-field area. Three techniques were used to evaluate effects of operation of the Bowline Point plant on community structure: diversity, cluster analysis, and niche breadth (ORU 1977:p. 6.1-55). These analytical techniques were used for 1976 data, which would be expected to exhibit any potential effects of the thermal discharge following 3 years of operation at the Bowline Point plant. Cluster analyses based on presence/absence of taxa and percent similarity indicate that no significant plume-related spatial variation occurred in taxonomic associations. From August through November the sample site located farthest downriver from the plant, and exposed to highest salinity, demonstrated low temporal variability compared with all other sites. Analysis of percent similarity indicated that this difference was due to presence or absence of nondominant taxa at the southern station. Niche breadth, which is a measure of the diversity of sampled habitats in which a species is found, and the evenness of the species' distribution, indicated that the seasonality of the major taxa decreased in the following order: blue-green algae, diatoms, and green algae. Shannon diversity indices, which may be used to identify changes in community structure in response to perturbations of that community, also indicate that temporal rather than spatial changes are more characteristic of the community structure in the Bowline Point plant plume and near-field areas. Diversity was low in the diatom-dominated spring community, increased to a maximum during the fall when the community was dominated by green and blue-green algae, and subsequently declined through winter.

4.2.3.2 Thermal Tolerance

Condenser entrainment studies conducted at the Bowline Point plant (EA 1977b: p. 2-2) indicate that the exposure duration and temperatures experienced by phytoplankton entrained into the thermal plume should not cause significant changes in photosynthetic production. Phytoplankton viability and productivity (as measured by carbon-14 uptake, carbon assimilation per unit chlorophyll, pigment concentrations, adenosine triphosphate levels, and flourescence microscopy) following entrainment were slightly reduced initially, but were not reduced 24 hours following collection. The recovery during the latent effects period may have resulted from the high reproductive capacity of most phytoplankton species. Since condenser entrainment involves mechanical as well as thermal stresses, and since the observed reductions due to condenser entrainment did not correlate with discharge temperatures, this suggests that the reductions observed were not a function of thermal stress. The small decrease in productivity observed during condenser entrainment survival studies therefore probably overestimates the effect which could be expected during plume entrainment. Thus, the thermal effects on phytoplankton entrained in the Bowline Point plume should be negligible.

The upper lethal temperature threshold for algae varies with species; however, Patrick (1969) reported that the lethal temperatures for most species ranged from 33.1 to 45.0 C (91.6 to 113 F) with the majority near 43.9 C (111 F). These lethal temperatures generally exceed maximum thermal plume temperatures at the Bowline Point plant. NYU (1974:p. 73) reported consistent reductions in phytoplankton productivity following 60-minute exposures to temperatures in excess of 38 C (100.4 F) after a relatively rapid temperature increase of 7 C (12.6 F) or more. Reductions in productivity due to 6-, 33-, and 60-minute exposures to an instantaneous 8 C (14.4 F) increase occurred only when test temperatures exceeded 30 C (86 F) (NYU 1975:p. 99). The results of condenser entrainment studies at various Hudson River power plants revealed inconsistencies in the effects of entrainment on phytoplankton survival and productivity at discharge temperatures between 28 and 35 C (82.4 and 95 F) (EA 1977b: p. 2-5), thus indicating that there was no clear dependence of productivity on discharge temperature. It was concluded that substantial reductions (greater than 10-20 percent) in productivity are not likely to occur at discharge temeratures below 38 C (100.4 F). Therefore, the entrainment of phytoplankton into even the warmest waters of the Bowline Point plant's thermal plume should not result in reductions in productivity.

4.3 MICROZOOPLANKTON

4.3.1 Evaluation Criteria

Microzooplankton generally have limited motility; their vertical and horizontal movement is mainly determined by water currents. Consequently, they are susceptible to entrainment within discharge plumes. Zooplankton may be herbivores, carnivores, or detritivores and are an important food source for higher trophic levels, in particular, young-of-the-year fishes (TI 1976a: pp. V-16 - V-17; LMS 1974a:pp. VI-75 - VI-80; LMS 1974b:pp. IV-151 - IV-155).

In this section, primary emphasis is placed upon an examination of nonpredictive data relating to microzooplankton abundance, distribution, and community structure within the Hudson River estuary to determine whether there is any indication that the thermal plume from the Bowline Point plant has caused prior appreciable harm to populations of these organisms. The information presented is based upon pre- and post-operational, near- and far-field studies conducted in the Bowline Point vicinity since 1971. In addition, some thermal tolerance data are included to predictively assess possible effects of the plant's cooling water discharge on these organisms.

This section is intended to provide resolution to the following evaluation criteria suggested in the 1 May 1977 draft of the EPA 316(a) Technical Guidance Manual (EPA 1977:p. 20):

1. Changes in the zooplankton community in the primary study area that may be caused by the heated discharge will not result in appreciable harm to the balanced indigenous fish and shellfish population.
2. The heated discharge is not likely to alter the standing crop, relative abundance, with respect to natural population fluctuations in the far-field study area from those values typical of the receiving water body segment prior to plant operation.

3. The thermal plume does not constitute a lethal barrier to the free movement (drift) of zooplankton.

4.3.2 Rationale

The Bowline Point thermal discharge has caused no appreciable harm to the microzooplankton community in the plant vicinity. Based on comparison and analysis of field data collected in the vicinity of the Bowline Point plant from 1970 to 1976, there is no indication that the plant's cooling water discharge has affected seasonal trends in abundance, distribution, or species succession of microzooplankton within the lower Hudson River estuary. No consistent differences were found between plume, near-field, and far-field stations, and occasional variation observed reflected naturally occurring environmental phenomena. Data from recent field surveys (1975-1976) conducted in the area of Bowline Point, and earlier surveys (1970-1971) conducted just north of Bowline Point, show no postoperational trends in seasonal succession or relative abundance of microzooplankton which are inconsistent with those of the receiving waterbody prior to plant operation.

Condenser entrainment survival studies, laboratory thermal effects experiments, and hydrothermal analyses of the Bowline Point plant's discharge plume (Chapter 3) demonstrate that any potentially stressful thermal conditions are confined to an extremely small area immediately adjacent to the discharge diffuser and exist only during the period of summer maximum ambient temperatures. Because of the rapid dilution of heat affected by the high-velocity discharge diffuser, organisms entrained into the plume directly in front of the diffuser are exposed to maximum discharge temperatures for only about 5-10 seconds. Based on the temperature tolerance of representative species of microzooplankton, plume entrainment is expected to result in little microzooplankton mortality.

The limited river width and cross-sectional area encompassed by the 2.2 C (4 F) isotherm make it unlikely that the Bowline Point thermal plume would have any far-field adverse effects. Due to its small size, the thermal plume does not constitute a lethal barrier to the free movement (drift) of microzooplankton.

Microzooplankton are a key segment in the aquatic food web and serve as a link between primary producers (phytoplankton) and higher trophic levels, such as fish. They also serve as food for other zooplankton. Since no appreciable alteration of the microzooplankton community has been detected in the vicinity of the Bowline Point plant or is predicted based on laboratory thermal effects studies and plume hydrothermal analyses, no adverse effects on normal predator-prey relationships is expected between microzooplankton and the other trophic levels with which they interact. Consequently, the Bowline Point thermal discharge is expected to cause no appreciable harm to microzooplankton communities, or to the communities of organisms that depend on microzooplankton as a food source.

4.3.3 Supportive Information

4.3.3.1 Distribution, Abundance, and Community Structure

The invertebrate microzooplankton community (organisms small enough to pass through a 571-µ mesh net) of the Hudson River estuary described by ORU (1977: pp. 7.3-2 - 7.3-10) varies from a predominantly marine aggregation in the lower estuary to a freshwater community in the upper estuary (Table 4.3-1). A transition zone marked by a mixture of both marine and freshwater species occurs from approximately MP 40 to MP 45, a region of highly variable salinity. During periods of high freshwater flow (greater than 23,000 cfs at the

TABLE 4.3-1 DOMINANT MICROZOOPLANKTON TAXA AT SPECIFIC POINTS IN HUDSON RIVER ESTUARY*

	Lower Estuary		Middle Estuary		Upper Estuary	
	Tappan Zee (MP 33) (TI 1975c)	Bowline Pt. (MP 38) (LMS 1976b)	I.P. (MP 42) (TI 1975a)	Cornwall[(a)] (MP 56) (TI 1975b)	Danskammer (MP 66) (LMS 1975a)	Kingston (MP 95) (LMS 1975b)
Rotifera	Present[(b)]	*Synchaeta* *Notholca* *Keratella* *Brachionus*	*Brachionus* *Notholca*		*Keratella* *Notholca* *Ploesoma* *Polyarthra*	*Brachionus* *Elosa* *Filinia* *Kellekotia* *Keratella*
Micro-crustacea	*Ectinosoma* *Canuella* *Eurytemora* *Microauthridino* *Cyclops* *Acartia*	*Halicyclops* *Ectocyclops* *Paracyclops* *Eurytemora* *Acartia*	*Eurytemora* *Acartia* *Bosmina* *Diaphanosoma*		*Bosmina* *Daphnia* *Leptodora*	*Bosmina* *Daphnia* *Leptodora* *Pleuroxus* Copepods[(b)]
Protozoa	(c)	(c)	*Centropyxis* *Difflugia*		(c)	(c)

(a) Comparable data not available.
(b) Species not given.
(c) Protozoa present but data not collected.

* Adapted from McFadden 1977:pp. 4-5).

Troy Dam) the freshwater or oligohaline community typical of the upper estuary dominates the middle estuary. However, when the salt front (0.1 ppt salinity) extends into the middle estuary during periods of low freshwater flow, the microzooplankton community shifts to a mixed aggregation of brackish and freshwater forms. The late summer distribution of the euryhaline copepod *Eurytemora affinis* in the upper fresh or slightly brackish areas and the restriction of the distribution of the marine copepod *Acartia tonsa* to more saline areas behind the salt front demonstrate these spatiotemporal patterns. Detailed descriptions of the spatial and temporal distributions of several dominant planktonic species in relation to salt-front movement are presented in ORU (1977:pp. 7.3-3 - 7.3-10), and further document the effect that salt balance in the partially mixed estuary (Hansen 1967:p. 45) has on the longitudinal microzooplankton community composition. The Bowline Point plant is located near the lower end of the freshwater-saltwater transition zone and the zooplankton community consists intermittently of freshwater and marine species (ORU 1977:p. 7.3-4). The relative abundance of the major groups varies by season and with water temperature. Therefore, it is necessary to identify the seasonal patterns of abundance and composition of the community in the vicinity of the Bowline Point plant in order to evaluate the possible effects of the cooling water discharge on that community.

Major components of the microzooplankton community in the vicinity of the Bowline Point plant are copepods, cladocerans, and rotifers (ORU 1977:p. 7.1-7). These same major groups dominate the zooplankton communities throughout the estuary (CHG&E 1977:Section 7.3; McFadden 1977:p. 4.5). Protozoa and larval stages of Mollusca and Annelida were occasionally collected during surveys conducted from 1971 to 1976 but were not abundant components of the community.

The postoperational (1975 and 1976) seasonal succession patterns in the vicinity of the Bowline Point plant reported by ORU (1977:p. 7.1-37), closely resemble far-field abundance patterns during the preoperational period (1970 and 1971) described by Lauer et al. (1974:p. 56). The microzooplankton community gradually increases from minimum abundance in winter to peak abundance in early summer and midsummer followed by a gradual decrease in late fall to the small winter population once again. Copepod nauplii (immature life stage) and postnaupliar copepods dominate the community during all seasons; abundance of nauplii increases through late summer as adults reproduce, then decreases as recruitment to the adult population occurs. Freshwater cyclopoid copepods (e.g., Halicyclops fosteri) are predominant throughout most of the year except during periods of low freshwater flow (late summer/early fall) when the more salinity tolerant calanoid copepods (e.g., A. tonsa) increase in abundance. Maximum cladoceran abundance occurs during midsummer but rarely constitutes greater than 10 percent of the community. Rotifers typically show a bimodal peak in abundance with the genera Keratella, Notholca, and Polyarthra most common during the spring peak, and Keratella alone responsible for the late fall peak. The late summer decline in abundance occurs when salinity and temperature are maximum while peak rotifer abundance parallels periods of high freshwater flow and cooler river ambient temperatures. The seasonal succession of the microzooplankton community has classically been associated with changes in ambient temperature, freshwater flow (and salinity), and phytoplankton biomass (Hulsizer 1976; Heinle 1974). These same general seasonal and relative abundance patterns in the distribution of microzooplankton within the lower Hudson River estuary near the Bowline Point plant have been observed prior to plant operation (Lauer et al. 1974:p. 56), as well as during the postoperational period (ORU 1977:Subsection 7.1.3.1.2). Thus, there is no indication that thermal additions from the Bowline Point plant, or the operation of the plant's cooling water system in general, has affected natural trends in seasonal microzooplankton abundance, distribution, or species succession within the estuary.

Statistical analyses of total microzooplankton abundance indicate significant variation among years, dates, and sample sites; however, differences between near- and far-field sites (Figures 4.3-1 and 4.3-2) were generally not significant (ORU 1977:pp. 7.1-12, 7.1-35). Cladocerans were the only microzooplankton consistently less abundant in the near-field zone, but this trend existed during both pre- and post-operational years.

Analysis of the community structure in the 1976 near- and far-field zones by ORU (1977:pp. 7.1-35 - 7.1-40) corroborated the strong seasonal succession patterns of microzooplankton and indicated the existence of some community differences between the near- and far-field zones which may be partially related to natural environmental variables. Cluster analysis indicated intrastation similarity for three seasonal periods: May, June, November, and December; July, August, September, and October; and March and April. These associations indicate a community succession from an early spring to late spring/early summer followed by a midsummer/early fall assemblage. The late fall community in November and December was similar to the late spring community associations. Five major species associations were identified which reflected the successional pattern identified by station similarity indices. The seasonal succession of these five assemblages of microzooplankton was partly influenced by changes in salinity in the vicinity of the Bowline Point plant. Species diversity and niche breadth indicated that no consistent differences existed between near-field and far-field stations except in March, April, and

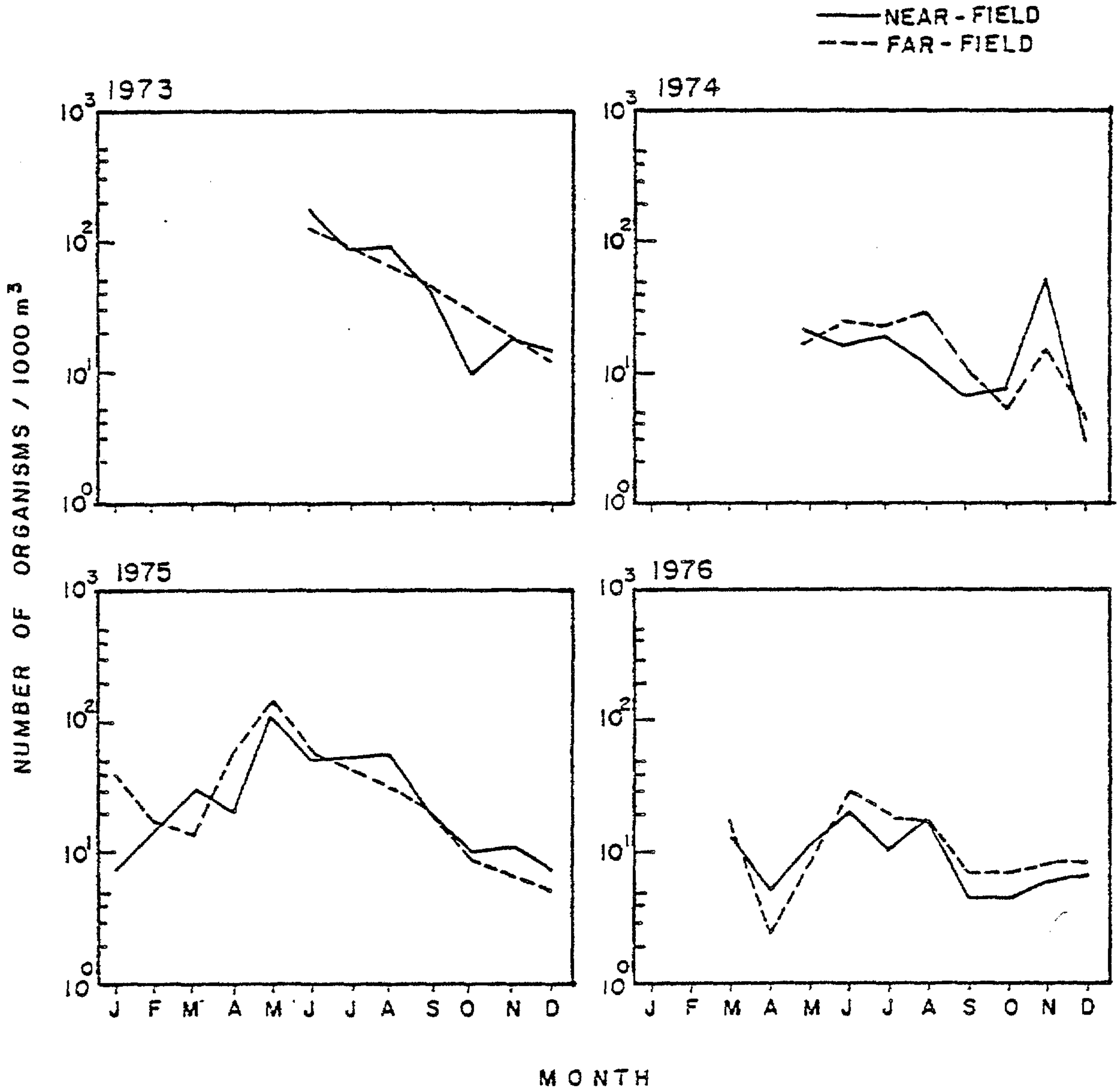


Figure 4.3-1. Abundance of total microzooplankton in the vicinity of the Bowline Point plant—1973-1976 (from ORU 1977:p. 7.1-15).

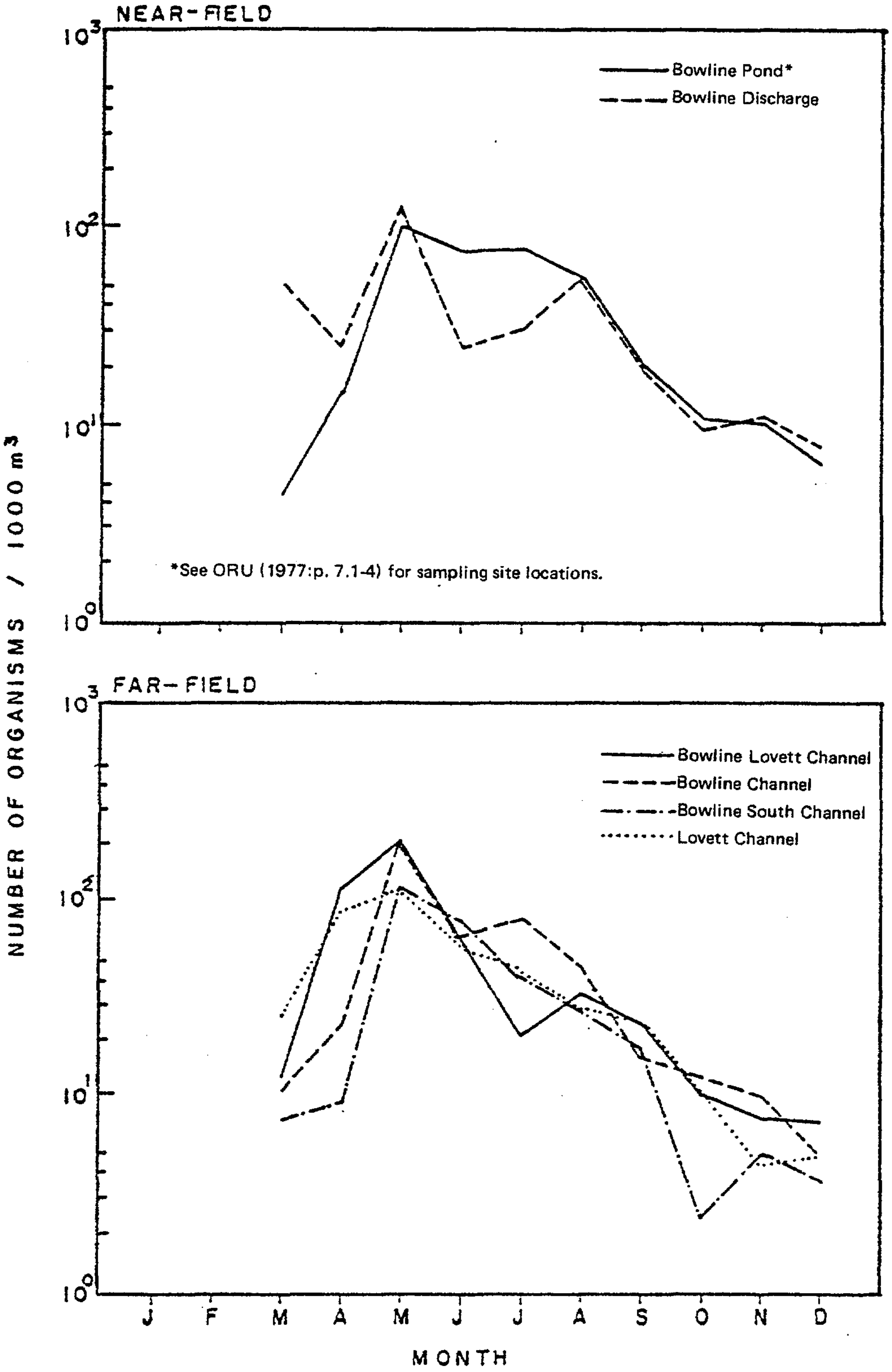


Figure 4.3-2. Abundance of total microzooplankton in day bottom collections in the vicinity of the Bowline Point plant—1975 (from ORU 1977:p. 7.1-27).

May. During this period, the community composition differed with several taxa (five in March, three in April, and two in May) occurring only in the near-field area (ORU 1977:pp. 7.1-46 - 7.1-48) indicating the existence of spatial variation in the spring community. In addition, the presence of the brackish copepod (*E. affinis*) during April and the marine copepod (*A. tonsa*) during May only at the far-field sites is probably influenced by the presence of denser saline water at the deeper far-field channel stations.

Thus, spatial differences in the vicinity of the Bowline Point plant generally reflected variation in natural physicochemical variables. Seasonal trends in microzooplankton community structure, distribution, and abundance in the vicinity of Bowline Point are consistent with those that typically occur within temperate estuaries. Occasional variation between populations within and outside the area of the thermal plume is attributed to periodic changes in natural environmental factors (e.g., salinity) and does not appear to be caused by plant operation.

4.3.3.2 Thermal Tolerance

Condenser entrainment and laboratory thermal effects studies indicate that the major microzooplankton species found in the vicinity of the Bowline Point plant have considerable tolerance to elevated temperatures. Tests to determine the survival of microzooplankton following condenser entrainment at the Bowline Point plant were conducted in 1975 and 1976. Entrainment durations varied from about 5.3 to 7.4 minutes depending on pump mode (EA 1977a: p. 4.2-16), and organisms were retained approximately 5 minutes at elevated temperatures in the sampling device. Results of these tests indicated high initial as well as latent survival. Mean initial entrainment survival calculated for total microzooplankton was 82.7 percent in 1975 and 95.5 percent for

1976. Mean 48-hour latent survival was 80.1 and 93.9 percent, respectively. No relationship was observed between entrainment mortality and discharge temperatures up to 37 C (98.6 F; the highest temperature tested), although a correlation was found between mortality and pumping mode. Thus, a significant portion of the estimated mortality was apparently caused by nonthermal (i.e., mechanical and pressure) stresses incurred during passage through the cooling water system (EA 1977a:pp. 4.2-19 - 4.2-36). Condenser entrainment studies at four other power plants located along the Hudson River estuary produced similar microzooplankton survival data (EA 1977b:p. 3-1).

The upper thermal tolerance threshold (TL95) of several major microzooplankters of the Hudson River estuary was examined by Lauer et al. (1974: p. 66). For Halicyclops fosteri, Bosminia longirostris, Eurytemora affinis, and Acartia tonsa acclimated to a summer ambient temperature of 24.6 C (76.3 F), upper lethal thermal thresholds observed for 15-minute exposures were 36.0 C (96.8 F), 34.7 C (94.5 F), 34.0 C (93.2 F), and 35.0 C (95.0 F), respectively. The thermal thresholds for 30-minute exposures were about 1 C (0.55 F) lower. In both cases, temperatures leading to 50 percent mortality of the species tested were about 2-3 C (3.6-5.2 F) higher than the threshold temperatures.

Short-term exposure (5-10 seconds) to elevated temperatures of up to about 35 C (95 F) during summer ambient conditions should therefore have little effect on the survival of microzooplankton found in the area of the Bowline Point plant. Temperature elevations of this magnitude would be expected to occur within the thermal plume only during the warmest summer months and would be confined to an extremely small area immediately adjacent to the discharge diffuser. Microzooplankton entrained at the point of discharge would experience an almost instantaneous (5-10 seconds) reduction in plume temperatures to less than half that of the maximum condenser delta-T (Subsection 3.3.1.4, Figure 3.3-3), thus greatly reducing the potential for heat stress.

The New York State thermal criteria infer that the aquatic community will be protected if organisms passing through no more than 67 percent of the river cross section are exposed to temperatures in excess of 2.2 C (4 F) above ambient. Since a maximum of only 5.5 percent of the cross-sectional area was observed to be within the 2.2 C (4 F) isotherm during thermal surveys conducted at near-capacity plant operation (93-99 percent) (Subsection 3.3.1.1, Table 3.3-1), the thermal plume of the Bowline Point plant is not expected to have an adverse effect upon the microzooplankton community of the Hudson River estuary. The high reproduction and growth rates of microzooplankton and short generation times enable microzooplankton populations to rapidly recover from any localized stresses which might occur in the immediate area of the discharge diffusers.

4.4 MACROINVERTEBRATES

4.4.1 Evaluation Criteria

In this section macroinvertebrates are divided into two groups based on habitat: macrozooplankton, those which are predominantly planktonic and epibenthic; and macrobenthos, those which are essentially benthic (i.e., generally occur on or in the bottom substrate). Each group is discussed in a separate subsection which presents information pertaining to evaluation criteria specified in the 1 May 1977 draft of the EPA 316(a) Technical Guidance Manual (EPA 1977: pp. 23-25). These criteria are summarized as follows:

1. Any detected reductions in standing crop of macroinvertebrates have caused no appreciable harm to the balanced indigenous populations within the waterbody segment.
2. Any detected reductions in the components of diversity will not interfere with maintainence of the critical functions of the macroinvertebrate fauna in the waterbody segment or alter them from the state in which they existed prior to the introduction of heat.
3. The thermal plume does not create a blockage to the free drift of macroinvertebrate fauna.
4. No spawning or nursery sites for important macroinvertebrates will be adversely impacted by the discharge of heat.

4.4.2 Macrozooplankton

4.4.2.1 Introduction

The macrozooplankton community (primarily organisms retained by a 571-μ mesh plankton net) within the Hudson River estuary includes organisms that are typically dependent on water currents for horizontal movement, but may exhibit diurnal vertical migration patterns; some forms occasionally assume a benthic resting state (e.g., the cladoceran *Leptodora kindti*). Macrozooplankton occupy a key position in the food web as both primary and secondary consumers, feeding on phytoplankton and zooplankton and, in turn, serving as prey for other zooplankton and fish. This subsection provides a nonpredictive evaluation based on field studies of macrozooplankton abundance, distribution, and community structure to determine whether elevated temperatures caused by the Bowline Point plant's thermal discharge have had any effect on the macrozooplankton community of the Hudson River estuary. These field studies were conducted in 1971 and from 1973 to 1976. The macrozooplankton species designated as RIS are *Neomysis americana*, *Crangon septemspinosa*, and *Gammarus* spp. A discussion of predicted involvement of these RIS with the thermal plume at the Bowline Point plant, based on life history and laboratory thermal effects studies, is presented in Chapter 5 (Subsections 5.3.4.10, 5.3.4.11, and 5.3.4.12).

4.4.2.2 Rationale

The Bowline Point plant's thermal discharge has caused no appreciable harm to the macrozooplankton community of the lower Hudson River. Extensive field studies in the thermal plume near-field and far-field areas have detected no significant trends in the spatial distribution of macrozooplankton which can be attributed to the operation of the Bowline Point plant. Seasonal variations in macrozooplankton species composition and abundance were similar during preoperational (1971) and postoperational field investigations (1973-1976) (Lauer et al. 1974; ORU 1977:Chapter 8). Thus, there have been no apparent reductions in standing crop or in the components of diversity as a result of the discharge of heat by the Bowline Point plant.

The limited extent of the thermal plume assures that it does not create a barrier to the free drift of macrozooplankton fauna. The maximum percentages of the river surface width and cross-sectional area occupied by the plume (7.9 and 5.5 percent, respectively) are well within New York State criteria, which were designed to protect aquatic organisms. Furthermore, because of the small plume size, the potential for the plume to encompass unique spawning or nursery areas for macrozooplankton is minimal. Thus, the Bowline Point thermal discharge has neither caused any prior appreciable harm to the macrozooplankton community in the plant vicinity, nor is it expected to cause any future harm. The protection and propagation of the balanced indigenous community is thus assured.

The design and location of the discharge structure minimize the duration of exposure to elevated temperatures for those macrozooplankton entrained into the thermal plume. Cooling water temperatures drop to within 4.3 C (7.7 F) of ambient within 5-10 seconds after passing through the high-velocity diffuser ports. As shown in Chapter 5, representative important species of macroinvertebrates are expected to suffer no mortality as a result of the thermal exposure incurred during plume entrainment. The spatial distribution data collected in the field investigations have revealed no reductions in densities in the plume area, thereby affirming the lack of adverse effects owing to plume entrainment.

4.4.2.3 Supportive Information

4.4.2.3.1 Distribution, Abundance, and Community Structure

The macrozooplankton community of the Hudson River estuary includes predominantly marine or brackish-water forms in the lower estuary and predominantly freshwater forms in upstream areas. A transition zone from MP 40 to MP 65 is marked by highly variable salinity and a mixed freshwater and marine fauna. The upriver areas are dominated by amphipods (mainly Gammarus spp.), dipteran larvae (Chaoborus punctipennis), and the cladoceran (L. kindti) (ORU 1977: p. 8.4-3). During periods of high freshwater flow (low salinity), these taxa also dominate the middle portion of the estuary. The marine and brackish forms, Neomysis americana, Crangon septemspinosa, and Monoculodes edwardsi, are the major taxa found in the lower estuary downstream of the salt front (0.1 ppt salinity), and in the middle estuary during periods of low freshwater flow (Table 4.4-1). Descriptions of the spatial and temporal distributions of several dominant planktonic species in relation to salt-front movement are presented in ORU (1977:pp. 8.4-3 - 8.4-11).

Five invertebrate orders and one species numerically dominated the macrozooplankton community in the vicinity of the Bowline Point plant during surveys detailed in ORU (1977:pp. 8.1-5 - 8.1-38, 8.4-11 - 8.4-16): Amphipoda, Isopoda, Decapoda (predominantly zoeae of the mud crab, Rhithropanopeus harrisii), Diptera, Cladocera (L. kindti), and Mysidacea (N. americana). Seasonal succession patterns are primarily a reflection of the seasonal fluctuation of these five major taxa. Field surveys conducted by Lauer et al. (1974:pp. 57-58) in the Indian Point plant near-field area (MP 39-43) during 1971 indicate that the same seasonal trends and relative abundance patterns existed in the lower estuary prior to operation of the Bowline Point plant.

Total macrozooplankton abundance exhibited trimodal maxima (spring/summer/fall) during 1971 and 1974-1976; abundance minima occurred during late spring and early fall (Lauer et al. 1974:p. 58; ORU 1977:p. 8.1-16). During the spring, abundance rapidly increases as water temperature increases. Am-

TABLE 4.4-1 DOMINANT MACROZOOPLANKTON TAXA AT SPECIFIC POINTS IN HUDSON RIVER ESTUARY*

Lower Estuary		Middle Estuary		Upper Estuary	
Tappan Zee (MP 33) (TI 1975c)	Bowline Point (MP 37.5) (LMS 1976b)	Indian Point (MP 42) (TI 1975a)	Cornwall(a) (MP 56) (TI 1975b)	Danskammer (MP 66) (LMS 1975a)	Kingston (MP 95) (LMS 1975b)
		Crustacea			
Neomysis	*Daphnia*	*Gammarus*	*Gammarus*	*Cyathura*	*Leptodora*
Gammarus	*Leptodora*	*Monoculodes*	*Daphnia*	*Leptodora*	Amphipoda(b)
Monoculodes	*Neomysis*	*Neomysis*	*Leptodora*	*Gammarus*	*Chiridotea*
Leptocheirus	*Gammarus*	*Diaphanosoma*(c)		*Chiridotea*	*Cyathura*
		Insecta			
(d)	(d)	*Chaoborus*	*Chaoborus*	*Chaoborus*	Ceratipogonidae
		Tendipedidae	Other Diptera	Tendipedidae	Tendipedidae

(a) 500-μ mest net, all other in 571-μ netting.
(b) Lower taxa not given.
(c) Lovett Plant area, LMS (1975c).
(d) Present, species not given.

*Note: Adapted from McFadden 1977:p. 4.6.

phipods (Gammarus daiberi and Monoculodes edwardsi) and, to a lesser extent, emerging dipteran larvae dominate the spring community. Recruitment of juveniles of the isopod Chiridotea almyra contributes to abundance in the late spring. As summer progresses, total macrozooplankton densities level off or decline, largely as a result of decreases in amphipod densities. Dipterans continue to increase in abundance throughout the summer, and marine or brackish-water forms begin to appear as the salt front penetrates the middle estuary. The cladoceran L. kindti may also become dominant during early summer, but usually declines as salinity increases during late summer. Marine decapods (primarily mud crab zoeae, R. harissii) and N. americana may dominate the community during the late summer and early fall months. The isopods Cyathura polita and Edotea triloba contribute significantly to the fall peak. As temperatures decline during the fall, abundance gradually decreases, reflecting declines in all major macrozooplankton groups. However, N. americana abundance does not decrease until freshwater flow begins to increase and salinity decreases. In both 1974 and 1975, total macrozooplankton abundance increased again in late fall (November-December) mainly because of increased amphipod abundance when salinity decreased. These seasonal abundance patterns are typical of a temperate zone estuary and have displayed no consistent shifts or trends related to the thermal discharge from the Bowline Point plant.

Spatial and temporal trends in macrozooplankton distribution from 1975 to 1976 (ORU 1977:pp. 8.1-38 - 8.1-51) indicate no localized reductions in abundance or changes in community composition attributable to the effects of the Bowline Point plant's thermal plume. Spatial distribution of total macrozooplankton and major taxonomic groups showed near-field and far-field interstation patterns of abundance that were similar during both years. In 1975 and 1976, abundance of total macrozooplankton, amphipods, and N. americana was generally within or near the upper range of abundance at other river stations beyond the influence of the plume. Dipteran abundance was typically greater in the discharge area than at the channel stations, which may be caused by a greater rate of emergence for individual species in the shallower shoal area than in the channel (ORU 1977:pp. 8.1-45, 8.1-51). These data indicate that spatial patterns are typically influenced by natural environmental variability, such as salt-front movement and habitat distribution, rather than by thermal discharges from the Bowline Point plant.

Total macrozooplankton, amphipod, and dipteran abundance during 1975 and 1976 were similar between years; however, N. americana and decapods increased slightly while L. kindti decreased (ORU 1977:p. 8.1-50). No consistent trends of decreasing or increasing abundance have occurred in the vicinity of the Bowline Point plant which would indicate a thermally induced alteration in the community.

Statistical comparisons of macrozooplankton near- and far-field community structure during 1974-1976 (ORU 1977:pp. 8.1-51 - 8.1-65) further indicated the existence of strong seasonal succession patterns and showed no consistent differences that could be attributed to the thermal discharge of the Bowline Point plant. Cluster analysis indicated intrastation similarity within the following seasonal groupings: early spring, late spring/early summer, midsummer/early fall, and late fall. These associations parallel seasonal abundance patterns and are related to such factors as freshwater flow, salinity, and seasonal ambient temperature. Species diversity values indicated salinity-induced seasonal differences between discharge and control zones during 1974 and 1975 that were not identified for 1976. These annual differences are probably produced by year-to-year differences in movement of the salt front (TI 1976b:pp. IV-27 - IV-31; ORU 1977:pp. 8.1-54 - 8.1-57).

4.4.3 Macrobenthos

4.4.3.1 Introduction

Macrobenthos are herein defined as the assemblage of bottom-dwelling organisms retained by a 420-µ mesh (No. 40 U.S. standard) seive. They represent primary and secondary consumer levels in the aquatic food web and, in turn, become food for higher trophic levels. Most of the macrobenthos groups in the vicinity of the Bowline Point plant and, in particular, oligochaetes and the dominant gastropods have little involvement with the plant's predominantly surface discharge plume. Dipterans have only a short period of exposure during emergence and egg deposition. As indicated in Subsection 4.4.3.3.1, only slight increases in temperature at the bottom resulting from the thermal discharge were encountered during the study period 1972-1976. Most macrobenthos taxa have very limited or no planktonic life stages which might be subject to drift through the primarily surface-oriented discharge plume. However, disruption of the integrity of producer or other consumer trophic levels could effectively alter the macrobenthos community structure. Therefore, data on far-field macrobenthos can be an indicator of general river and regional conditions. In addition, most macrobenthic species are not migratory in nature, and do not respond to adverse conditions by movement out of the area of disturbance. Because of this sedentary habit and the relative length of their life cycles, direct or indirect effects of thermal plume exposure can be more clearly isolated and defined for the macrobenthos than for some other trophic levels.

4.4.3.2 Rationale

The Bowline Point plant's thermal discharge has in no way altered the community structure or relative abundance of the macrobenthos in the plant vicinity. Based on analyses presented in ORU (1977:Chapter 8) there have been no statistical or observed differences between near- and far-field macrobenthos abundance data for the years 1972-1976 which can be associated with factors other than natural environmental variation. Spatial and temporal distributions of macrobenthos have shown no trends within or between discharge and unaffected zones that suggest any effects of the plume on benthic organisms either directly or through changes in other trophic levels.

No major spawning or nursery sites for important benthic macroinvertebrates have been adversely impacted by the thermal discharge from the Bowline Point plant. Spawning and nursery sites for macrobenthic fauna within the Hudson River estuary are not restricted to small geographical areas or unique ecological habitats. Instead, these organisms utilize a considerable portion of the estuary for these critical activities. Of this area, only a very small segment is affected by the thermal plume from the Bowline Point plant. Furthermore, reproduction of relatively sedentary benthic forms appears to have successfully continued in the area of the discharge plume as is indicated by plume population abundances and community composition similar to those occurring outside of the thermally affected area.

Thus, the Bowline Point plant's thermal discharge has neither caused any prior appreciable harm to the macrobenthic community in the plant vicinity, nor is it expected to cause any future harm. The protection and propagation of the balanced indigenous community is thus assured.

4.4.3.3 Supportive Information

4.4.3.3.1 Distribution, Abundance, and Community Structure

The distribution of macrobenthos in unaltered environments can be highly variable and is largely dependent upon characteristics of the substratum, such as organic content, mean particle size, and the salinity and temperature of the overlying water column. The benthic environment in the near- and far-field zones of the Bowline Point plant is described in ORU (1977:pp. 8.1-84 - 8.1-93), based on data collected between 1972 and 1976. Bottom temperatures varied less than 2 C (3.6 F) between stations for each sample date; however, only in December was this variability occasionally related to the discharge plume coming in contact with the bottom. Bottom sediments in the vicinity of the Bowline Point plant exhibited considerable annual, seasonal, and spatial variability due, in part, to variation in freshwater flow and river currents. Sediments were generally characteristic of relatively quiet water with high percentages of silt, particularly in deeper areas; the discharge area had a higher sand portion than much of the far-field zone, probably as a result of runoff from Minisceongo Creek, installation of the discharge, and discharge currents. Organic content averaged approximately 10 percent and generally increased from north to south and with water depth.

The benthic community in the vicinity of Bowline Point is dominated by gastropods, crustaceans, dipterans, oligochaetes, and polychaetes (Figure 4.4-1); the gastropod *Amnicola* spp. was the dominant taxa comprising up to 81.3 percent of the mean total benthos of river stations. *Amnicola* was the only gastropod genus collected. This snail typically breeds in the summer; abundance increases through the fall and then decreases to an overwintering population. The shift in peak seasonal abundance from fall (1972, 1973) to

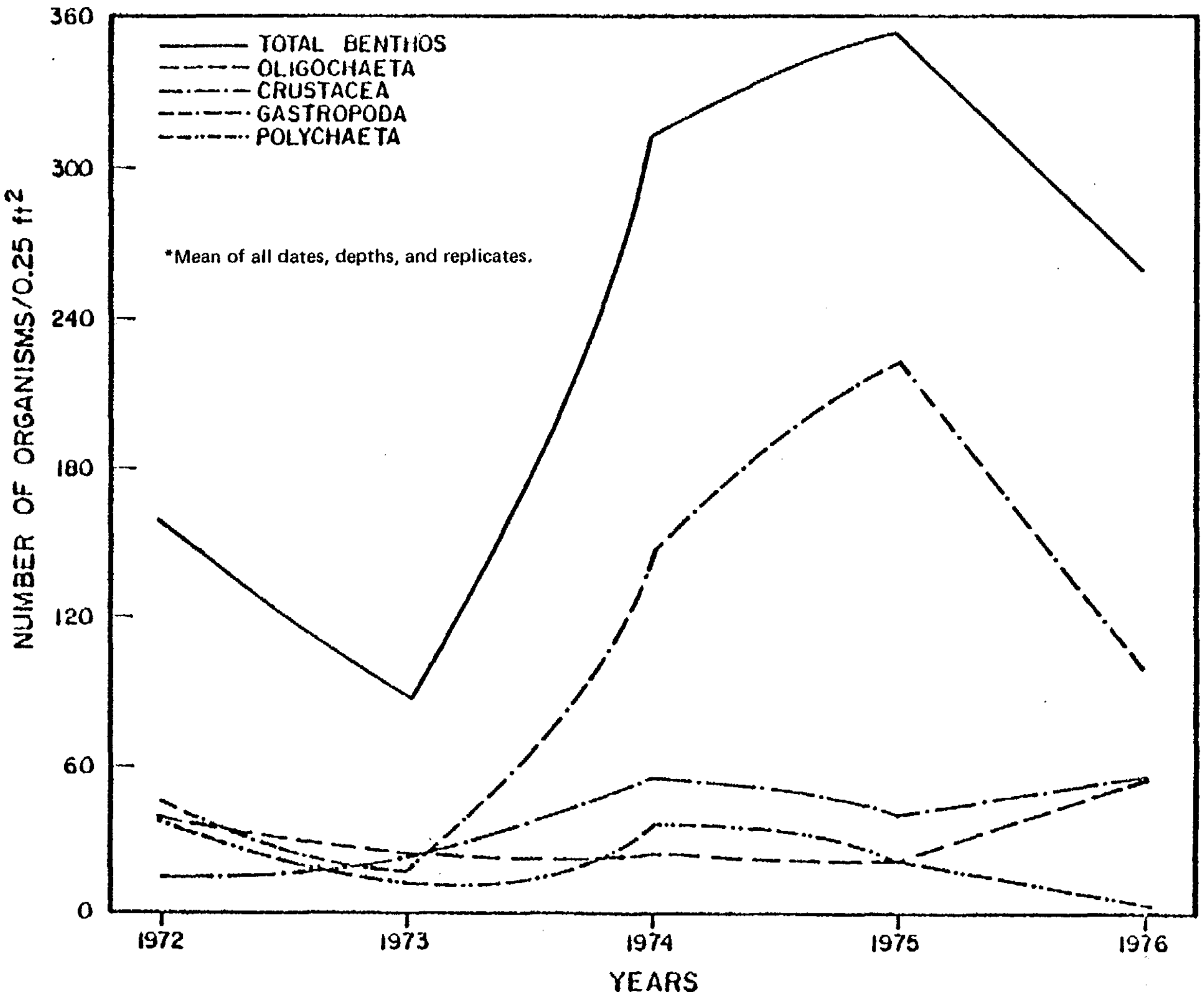


Figure 4.4-1. Mean* annual abundance of the major macrobenthos groups in the vicinity of the Bowline Point plant—1972-1976 (from ORU 1977:Figure 8.1-54).

winter (1974, 1975) to summer (1976) was in response to increases in *Amnicola* abundance during 1974 and 1975. Because of the small size of *Amnicola* there was no such shift in peak biomass; biomass generally peaked during the summer except when crustacean biomass exhibited a marked increase in December 1973. The dominant oligochaete *Scolecolepides viridis* showed peak abundance in the late summer or fall. Dipteran larvae typically increased in numbers through the summer.

Over the 5-year period (1972-1976) changes in the benthos have not been unidirectional; rather they have involved normal cycles with both decreases and increases. Total abundance reflected the abundance of the dominant gastropod *Amnicola*, which was low in 1973, increased in 1974 and 1975, and then decreased in 1976. Polychaete, dipteran, and crustacean annual abundance fluctuated in a cyclic manner. Oligochaetes did not display this trend, but, as noted by Ristich et al. (1977:p. 261), the Bowline Point area marks the southern boundary of their distribution in the Hudson River because of their high sensitivity to increases in salinity.

Populations of most macrobenthic species in the polyhaline mud-bottom community are quite variable on a seasonal and long-term basis, as Boesch et al. (1976:p. 177) found in a 16-year study of benthos dynamics in the lower York River estuary in southern Chesapeake Bay. The dynamics of the populations reflected the life histories of the individual species and long-term natural habitat changes. Few common species were persistent and most were either irruptive annuals or euryhaline opportunists responding to habitat changes. Boesch et al. also suggested that benthic communities in temperate coastal and estuarine environments are generally characterized by wide fluctuations in abundance of the many constituent species, but that there is a more persistent qualitative composition on higher taxonomic levels such as was seen in the benthos community in the vicinity of Bowline Point.

The variability seen in long-river (Table 4.4-2), seasonal, and annual distribution patterns in the vicinity of the Bowline Point plant is indicative of, and inherent in, a dynamic estuarine ecosystem that is subject to environmental fluctuations on a seasonal as well as long-term basis. Long-term trends of abundance were similar at plume, near-, and far-field stations, which suggests that the community variations observed were not associated with the thermal discharge. The distribution trends of total benthos, dipterans, and polychaetes in the Bowline Point plant vicinity were similar for all stations (Figure 4.4-2) in and out of the zone of thermal influence. However, slightly lower total benthos abundance at the discharge transect during 1974, 1975, and 1976, and higher abundance at this transect during 1973 appeared to be related to the distribution of *Amnicola*. This decrease was only slight (abundance still remained high) and did not significantly alter the community structure. A habitat preference by *Amnicola* for areas protected from currents, such as those associated with the discharge, may account for this trend (ORU 1977: pp. 8.1-127).

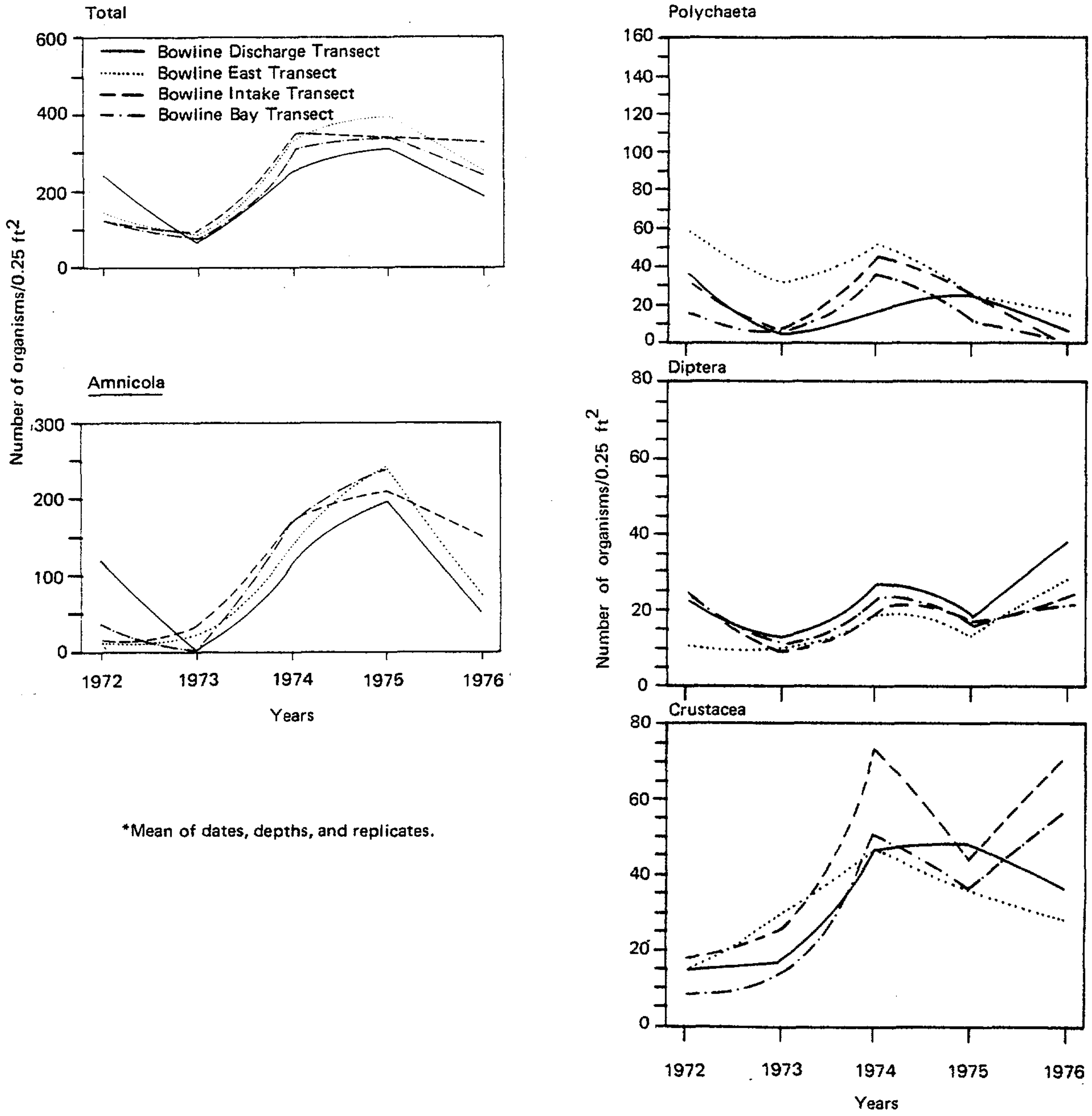
Cluster analysis (ORU 1977:pp. 8.1-136 - 8.1-144) indicated that the benthic community at all river stations was similar during 1973-1976 with no effect of depth or geographic location. Shannon diversity indices showed no significant differences between the far-field and discharge stations as expected from the consistent relative abundance of the major taxa (Figure 4.4-2) and the dominance of *Amnicola*. It is therefore apparent that no changes in the structure of the benthic community have been caused by the thermal discharge from the Bowline Point plant.

TABLE 4.4-2 DOMINANT BENTHIC INVERTEBRATE TAXA AT SPECIFIC POINTS IN HUDSON RIVER ESTUARY*

Lower Estuary		Middle Estuary		Upper Estuary	
Tappan Zee (MP 33) (TI 1975c)	Bowline Point (MP 37.5) (LMS 1976b)	Indian Point (MP 42) (TI 1975a)	Cornwall (MP 56) (TI 1975b)	Danskammer(a) (MP 66) (LMS 1975a)	Kingston(a) (MP 95) (LMS 1975b)
Annelida					
Peloscolex *Scolecolepides*	*Peloscolex* *Limnodrilus* *Hypaniola*	*Scolecolepides* *Limnodrilus* *Boccardia*	*Limnodrilus* *Scolecolepides*	*Scolecolepides*	Oligochaeta
Crustacea					
Harpacticoida *Cyathura* *Balanus* *Leptocheirus*	Harpacticoida *Cyathura* *Leptocheirus*	*Balanus* *Cyathura* *Leptocheirus* *Gammarus*	Harpacticoida *Cyathura* *Gammarus*	*Cyathura* *Gammarus*	*Cyathura*
Insecta					
	Tendipedidae	Tendipedidae	Tendipedidae	Diptera(b)	Diptera(b)
Mollusca					
Amnicola *Congeria*	*Amnicola*	*Amnicola* *Congeria*	*Sphaerium*	*Sphaerium* *Lampsilis*	(c)
Other					
Nematoda	Bryozoa Chaetognatha	Bryozoa	Nematoda Bryozoa		

(a) From taxon list and text discussion.
(b) Includes Tendipedidae.
(c) Molluscs a major component, subdivisions not specified.

*NOTE: Adapted from McFadden 1977:p. 4.4.



*Mean of dates, depths, and replicates.

Figure 4.4-2. Mean annual abundance* of Amnicola, polychaetes, dipterans, crustaceans, and total in macrobenthos collections in the vicinity of the Bowline Point plant, 1972-1976 (adapted from ORU 1977: Figures 8.1-52 and 8.1-53).

4.5 HABITAT FORMERS

The Hudson River estuary in the vicinity of Bowline Point is considered an area of "low potential impact" for habitat formers. This area is essentially devoid of all colonial macroinvertebrate taxa that could provide a substrate for other trophic levels. Sedimentation and seasonal and annual variation in the sediment composition of the bottom substrate (ORU 1977:Subsection 3.1.1.3) limit the development of sessile aggregations of plants or animals. Moreover, the relatively turbid character of the lower Hudson River estuary limits rooted aquatic vegetation almost entirely to "...shallow bays, shoals, and the mouths of tributaries where water depth is less than 10 ft at low tide" (LMS 1975c:p. VI-17). Since these limiting factors are natural characteristics of the aquatic environment at Bowline Point, it is unlikely that any change in the system will occur that would otherwise permit establishment of a faunal community of habitat formers or extension of the macrophyte community.

Seasonal surveys of the littoral zone macrophyte community in the vicinity of Bowline Point (MP 36-42) conducted in April, July, September, and November 1974 by LMS (1975c:pp. VI-17 - VI-21) indicated that the distribution and community composition of rooted aquatic vegetation varied with seasonal fluctuations in river temperature. High relative abundance and diversity of macrophytes occurred during summer and early fall commensurate with the period of maximum or near maximum annual temperatures, whereas little or no growth was evident during early spring or late fall. *Myriophyllum spicatum*, *Potamogeton perfoliatus*, and *P. crispus* were dominant throughout the study area. During the July survey, *P. perfoliatus* was the most abundant species in the northern portion of the study area, and the other two species were dominant to the south. By September, however, *M. spicatum* had become dominant throughout the entire sampling area, and by November, macrophyte species had all but disappeared from the Bowline Point area, with the exception of M. spicatum, which formed narrow bands along the shoreline.

In view of the offshore location and rapid dilution of heat effected by the Bowline Point plant's high-velocity diffuser discharge, neither the nearshore macrophyte community (restricted by light penetration to depths of <10 ft below low tide), nor any shore zone emergent marshes (McFadden 1977:p. 3.2) come in contact with the 2 C (3.6 F) temperature rise isotherm of the thermal plume (Subsection 3.3.1.2, Figure 3.3.1). Consequently, the cooling water discharge from the Bowline Point plant is not expected to have any effect on either emergent or submerged rooted aquatic vegetation, the principle habitat formers within this portion of the Hudson River estuary.

4.6 FISH

4.6.1 Introduction and Evaluation Criteria

The effects of thermal discharge from the Bowline Point plant on fish are discussed for the early life stages (ichthyoplankton) and older life stages (juveniles and adults). The evaluation criteria applicable to ichthyoplankton are those presented for microzooplankton in Subsection 4.3.1. Evaluation criteria for juvenile and adults are those presented below (EPA 1977:p. 29). Those criteria require that no appreciable harm be incurred by the fish community from:

1. Direct or indirect mortality from cold shock.
2. Direct or indirect mortality from excess heat.
3. Reduced reproductive success or growth as a result of plant discharges.
4. Exclusion from unacceptably large areas.
5. Blockage of migration.

In Chapter 5, it is demonstrated that the Bowline Point thermal discharge will cause no appreciable harm to the balanced indigenous community as represented by the selected RIS. That demonstration is based on a predictive evaluation of thermal impact in relation to the above criteria drawing upon such data sources as thermal effects laboratory study results, life history and distribution information, and hydrothermal data pertaining to thermal discharge plume. The intent of the present section, in contrast to that of Chapter 5, is to demonstrate that the Bowline Point plant's thermal discharge has caused no prior appreciable harm to the balanced indigenous community, and to identify the natural trends in abundance and community structure which have occurred during the period of operation of the plant.

4.6.2 Rationale

The fish community of the Hudson River has not suffered prior appreciable harm because of the thermal discharge from the present once-through cooling system at the Bowline Point plant. The normal movement of the major fish species to deeper channel areas in the fall has not been altered and no winter concentration of fish has been observed in the discharge area.

Data presented in ORU (1977:Chapter 10) indicate that the Bowline Point plant's thermal discharge has not altered the rate of sexual maturation or fecundity of the major species found in the vicinity. Furthermore, the data also indicate that no consistent differences exist between growth rates in the near- and far-field areas. Trends and fluctuation in rate of growth in the first 2 years of life have generally existed since 1971, prior to operation of the Bowline Point plant.

McFadden (1977), ORU (1977), and TI (1976c) have demonstrated substantial annual variability in fish egg and larval distribution and abundance in the Hudson River estuary in response to environmental variables (salinity, freshwater flow, ambient temperature). There is no evidence which indicates that abundance of the early life stages of any species has decreased as a result of thermal discharges from the Bowline Point plant. Furthermore, field data indicate that the principal spawning areas of migratory species, such as striped bass, Atlantic tomcod, and clupeids, are located north of the thermal plumes from the Bowline Point, Lovett (MP 42), and Indian Point (MP 43) plants, and that egg and larval abundance have remained relatively stable. This supports the conclusions that spawning migrations have not been disrupted by the thermal discharge.

For most of the RIS which spawn in the Hudson River, areas of peak spawning and maximum egg and larval abundance are not located in the immediate vicinity of the Bowline Point plant. As a result of the high velocity and rapid dilution at the discharge-diffuser the maximum extent of the warmest portion of the plume is very small. Therefore, the involvement of those species and life stages in the vicinity of the plant with the warmest portion of the plume is low. Based on the wide distribution of these species, it is apparent that the Bowline Point plant plume does not occupy or exclude any unique spawning or nursery habitats and does not interfere with the normal longitudinal movements of early life stages.

4.6.3 Supportive Information

4.6.3.1 Introduction

This subsection presents a summary of the data available concerning the distribution, abundance, and community structure of the fish populations within the lower Hudson River in the vicinity of Bowline Point. The purpose of this section is to describe briefly the important parts of the data base for the demonstration of the absence of prior appreciable harm resulting from the discharge of heat by the Bowline Point plant.

Pertinent life history information for the more ubiquitous or seasonally abundant species found in the Hudson River below the Troy Dam is provided by TI

(1976c:pp. V-1 - V-183), McFadden* (1977:pp. 5.1 - 5.51), ORU (1977:pp. 9.1-62), and EA (1978b). A list of all species collected in the vicinity of the Bowline Point plant from 1971 through 1976 (ORU 1977:pp. 10.1-14 - 10.1-15) and their utilization of the estuary is provided in Table 4.6-1. Total numbers and relative abundance by year are presented in ORU (1977:Table 10.1-5).

4.6.3.2 General Discussion

The number of species collected in the shore zone of the Hudson River estuary varies seasonally in a pattern typical of temperate water bodies (McFadden 1977:Section 5.6). Numbers increase through the spring to a midsummer maximum, then decrease through December; a similar pattern is found in deeper areas. This pattern is primarily a result of movement of resident species between the shore zone and deeper water, as well as the seasonal occurrence within the estuary of nonresident and marine species. The seasonal disappearance and reappearance in the shore zone area of common resident species, such as white perch, are best explained by seasonal onshore-offshore movement in response to environmental variables and life history factors since many of these species are collected by deep water sampling gear during their absence from the shore zone (see McFadden 1977:p. 6.34, Figure 6.3-3). Occasional and seasonal marine species enter the saline portion of the lower estuary, particularly in summer and early fall; much of the increase in number of species in the lower portion of the estuary is due to this occurrence. Anadromous species such as striped bass, American shad, alewife, and blueback herring enter

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* McFadden (1977:Chapter 6) provides life stage distribution maps for striped bass, white perch, _Alosa_ spp., American shad, and Atlantic tomcod in the Hudson River estuary.

TABLE 4.6-1 FISH SPECIES COLLECTED IN ALL GEAR IN THE VICINITY OF THE BOWLINE POINT PLANT FROM 1971 THROUGH 1976 WITH NOTES ON OCCURRENCE AND HABITAT UTILIZATION

Species	Principal Usage of Estuary[a]	Year[b]					
		1976	1975	1974	1973	1972	1971
Lampreys - Petromyzontidae							
Sea lamprey	M-F Anadromous; incidental	-	+	-	-	-	-
Sturgeons - Acipenseridae							
Shortnose sturgeon	M-F Life resident; spawning (Sp)	+	+	+	-	+	-
Atlantic sturgeon	M-F Resident during early years; larger adults anadromous; spawning (Sp)	+	+	+	+	+	+
Freshwater eels - Anguillidae							
American eel	M-F Catadromous; nursery adult feeding	+	+	+	+	+	+
Herrings - Clupeidae							
*Blueback herring	M-F Anadromous; spawning (Sp); nursery (SP-F)	+	+	+	+	+	+
*Alewife	M-F Anadromous; spawning (Sp); nursery (S-F)	+	+	+	+	+	+
*American shad	M-F Anadromous; spawning (Sp); nursery (S-F)	+	+	+	+	+	+
Atlantic menhaden	M-F Nursery (Sp-S); adult feeding lower estuary	+	+	+	+	+	+
Gizzard shad	M-F Nursery (S-W)	+	+	+	-	-	-
Anchovies - Engraulidae							
*Bay anchovy	M-F Life resident; spawning (Sp-S)	+	+	+	+	+	+
Smelts - Osmeridae							
Rainbow smelt	M-F Anadromous; spawning (Sp); nursery (S-F)	+	+	+	+	+	+
Pikes - Esocidae							
Chain pickerel	F Life resident; spawning (W-Sp)	-	+	-	-	-	-
Mudminnows - Umbridae							
Eastern mudminnow	F Incidental; tributary spawner	-	+	-	-	-	-
Minnows & carps - Cyprinidae							
Goldfish	F Life resident; spawning (Sp)	+	+	+	+	+	-
Carp	F Life resident; spawning (Sp-S)	+	+	+	+	+	+
Golden shiner	F Life resident; spawning (Sp-S)	+	+	+	+	+	+
Emerald shiner	F Life resident; spawning (Sp-S)	-	+	+	+	-	-
*Spottail shiner	F Life resident; spawning (Sp-S)	+	+	+	+	+	+
Common shiner	F Life resident; (tributary streams)	-	-	-	+	-	-
Suckers - Catostomidae							
White sucker	F Life resident; spawning (Sp)	+	+	+	+	+	-
Freshwater catfishes - Ictaluridae							
White catfish	F Life resident; spawning (Sp)	+	+	+	+	+	+
Brown bullhead	F Life resident; spawning (Sp-S)	+	+	+	+	+	+

(a) General salinity distributions: F = limited to fresh or low-salinity waters; M = limited to marine or brackish waters; M-F = occurs in both marine and fresh waters (euryhaline); Sp = Spring, S = Summer, F = Fall, W = Winter.

(b) Plus (+) indicates present; minus (-) indicates absent.

Note: * indicates common Bowline Point fish fauna.

TABLE 4.6-1 (CONT.)

Species	Principal Usage of Estuary(a)	1976	1975	1974	1973	1972	1971
Hakes - Merlucciidae							
Squirrel hake	M Incidental; marine spawner	-	+	-	-	-	-
Cods - Gadidae							
*Atlantic tomcod	M-F Spawning (W); nursery (Sp-F); adult feeding	+	+	+	+	+	+
Needlefishes - Belonidae							
Atlantic needlefish	M-F Nursery (S); adult feeding (S)	+	-	+	-	-	-
Killifishes - Cyprinodontidae							
*Banded killifish	F Life resident; spawning (Sp-S)	+	+	+	+	+	+
Mummichog	M-F Life resident; spawning (Sp-S)	+	+	+	+	+	+
Silversides - Atherinidae							
Tidewater silverside	M-F Life resident; spawning (Sp-S)	+	+	-	-	+	+
Atlantic silverside	M-F Life resident; spawning (Sp-S)	+	+	+	+	+	+
Sticklebacks - Gasterosteidae							
Fourspine stickleback	M-F Life resident; spawning (Sp-S)	+	+	-	-	-	+
Pipefishes & seahorses - Syngnathidae							
Northern Pipefish	M-F Nursery (S); adult feeding (S)	+	+	-	+	+	-
Temperate basses - Percichthyidae							
*White perch	M-F Anadromous; spawning (Sp-S) nursery (Sp-F); feeding (Sp-F)	+	+	+	+	+	+
*Striped bass	M-F Anadromous; spawning (Sp) nursery (S-F) feeding	+	+	+	+	+	+
Sunfishes - Centrarchidae							
Rock bass	F Life resident; spawning (S)	+	-	-	-	-	-
Red breast sunfish	F Life resident; spawning (S)	+	+	+	+	+	+
*Pumpkinseed	F Life resident; spawning (S)	+	+	+	+	+	+
Bluegill	F Life resident; spawning (S)	+	+	+	+	+	+
White crappie	F Life resident; spawning (S)	-	-	-	+	-	-
Largemouth bass	F Life resident; spawning (S)	+	+	+	+	+	+
Black crappie	F Life resident; spawning (S)	-	+	-	+	-	-
Smallmouth bass	F Life resident; spawning (S)	+	+	-	+	-	-
Perches - Percidae							
*Tessellated darter	F Life resident; spawning (Sp)	+	+	+	+	+	+
Yellow perch	F Life resident; spawning (Sp)	+	+	+	+	+	+
Bluefishes - Pomatomidae							
*Bluefish	M-F Nursery (S); yearling feeding (S-F)	+	+	+	+	+	-

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(a) General salinity distributions: F = limited to fresh or low-salinity waters; M = limited to marine or brackish waters; M-F = occurs in both marine and fresh waters (euryhaline); Sp = Spring, S = Summer, F = Fall, W = Winter.

(b) Plus (+) indicates present; minus (-) indicates absent.

TABLE 4.6-1 (CONT.)

Species	Principal Usage of Estuary(a)	1976	1975	1974	1973	1972	1971
Jacks & pompanos - Carangidae							
Crevalle jack	M-F Nursery (S)	+	+	+	+	+	+
Drums - Sciaenidae							
Weakfish	M-F Marine spawner; nursery (S)	+	+	+	+	+	+
Spot	M-F Nursery (S)	+	-	-	+	-	-
Atlantic croaker	M-F Nursery (F)	-	-	+	-	+	-
Cunners - Labridae							
Tautog or Blackfish	M Incidental; marine spawner	-	-	-	+	-	-
Mullets - Mugilidae							
White mullet	M Nursery (S-F)	-	-	+	-	-	-
Soles - Soleidae							
*Hogchoker	M-F Life resident; spawning (S)	+	+	+	+	+	+

(a) General salinity distributions: F = limited to fresh or low-salinity waters; M = limited to marine or brackish waters; M-F = occurs in both marine and fresh waters (euryhaline); Sp = Spring, S = Summer, F = Fall, W = Winter.
(b) Plus (+) indicates present; minus (-) indicates absent.
Note: * indicates common Bowline Point fish fauna.

the river for a short period as adults to spawn in early spring and summer; the young may use the river as a nursery for a year or more. The young of predominantly marine species, such as weakfish, bluefish (Pomatomus saltatrix), and Atlantic menhaden (Brevoortia tyrannus) use the river briefly as a nursery area after being spawned in coastal waters. A large increase of freshwater species occurs in the upper portion of the river near Albany. Throughout the rest of the river, increases in species' numbers occur as a result of the shoreward movement of resident species, longitudinal shifts in distribution from upstream and downstream areas, and occasional occurrence of stream species that primarily inhabit tributaries of the estuary.

Comparison of relatively comprehensive river-wide surveys conducted in 1936 (Greeley 1937) and 1965-1975 (TI 1977:pp. V-27 - V-29; McFadden 1977:p. 5.85) indicates that the fish community composition of the Hudson River estuary has changed little since 1936; differences observed were due primarily to rare or occasional occurrences, and greater sampling intensity in the later surveys. During the 1975 survey, 90 species were collected compared to 58 species collected during 1936.

A total of 51 species were collected from 1971 through 1976 in the vicinity of the Bowline Point plant, ranging from 30 species in 1971 to 43 species in 1975 (ORU 1977:p. 10.1-232). Based on bottom trawl collections from three stations sampled during all 6 years near the Bowline Point plant, the annual number of species ranged from 20 to 29 (mean approximately 26) for the 1971-1976 period. Although annual differences in the total number of fish collected near the Bowline Point plant were due primarily to changes in sampling effort (ORU 1977:p. 10.1-13), shifts in relative abundance were apparent during the 6-year period (Table 4.6-2). These shifts were caused by significant, but inconsis-

TABLE 4.6-2 RELATIVE RANKING OF THE THREE MOST ABUNDANT FISH SPECIES COLLECTED IN THE VICINITY OF THE BOWLINE POINT POWER PLANT FROM 1971 to 1976

	1971		1972		1973	
Rank	Species	Percent	Species	Percent	Species	Percent
1	White perch	41.3	White perch	28.6	Bay anchovy	42.3
2	Striped bass	23.1	Bay anchovy	25.9	White perch	17.7
3	Alewife	9.2	Atlantic tomcod	14.6	Spottail shiner	9.4
		73.6		69.1		69.4

	1974		1975		1976	
Rank	Species	Percent	Species	Percent	Species	Percent
1	Atlantic tomcod	37.7	White perch	29.0	White perch	26.9
2	White perch	16.9	Hogchocker	22.7	Hogchoker	24.0
3	Hogchocker	15.6	Bay anchovy	12.2	Atlantic tomcod	7.8
		70.2		63.9		58.7

tent, shifts in abundance of marine species such as bay anchovy, bluefish, weakfish, Atlantic silverside (Menidia menidia), Atlantic menhaden, crevalle jack (Caranx hippos), and spot (Leiostomus xanthurus) which were related to differences in freshwater flow (salt-front location) (TI 1976c:pp. IV-26 - IV-30). This effect is further emphasized by comparison of the relative abundance of the major species near the Bowline Point plant with that in the freshwater area near Kingston (MP 95). At Kingston, blueback herring, white perch, and spottail shiner maintained the same relative rank and accounted for approximately 85 percent of the catch from 1971-1973 (Table 4.6-3). At the Bowline Point plant only white perch ranked among the top three species in all years, although its relative rank changed from year to year. Changes in community composition observed in the vicinity of the Bowline Point plant, therefore, appear to be related to natural physicochemical variability (freshwater flow and salt-front movement).

McFadden (1977:p. 5.68) reported that seasonal consistency of species richness in the lower portion of the river indicated that the lower estuary, particularly from Haverstraw Bay to Cornwall (MP 34-56), supports the most diverse community in the river. This diversity is a result of the distribution of freshwater, brackish, and marine species near the salt front. Diversity was determined in ORU (1977:pp. 10.1-58 - 10.1-69) for three trawl stations: one in the channel outside the plume influence (near field), the second at the discharge, and the third in a shallow shoal area inshore of the discharge diffuser. Generally, the Shannon-Wiener diversity values indicated that the shallower station had the highest community diversity, which may result from the movement of juveniles of many species into littoral zone nursery areas. No apparent difference was observed between the plume and channel stations; seasonal diversity varied among years but displayed no long-term trends in

TABLE 4.6-3 RELATIVE RANKING OF THE THREE MOST ABUNDANT FISH SPECIES COLLECTED IN THE VICINITY OF KINGSTON FROM 1971 TO 1973

	1971		1972		1973	
Rank	Species	Percent	Species	Percent	Species	Percent
1	Blueback herring	72.0	Blueback herring	32.5	Blueback herring	52.2
2	White perch	9.0	White perch	31.9	White perch	22.2
3	Spottail shiner	7.4	Spottail shiner	19.3	Spottail shiner	7.9
		88.4		83.7		82.3

either area from 1971 to 1976. Annual variation appeared to be related to differences in freshwater flow between years, rather than operation of the Bowline Point plant.

Cluster analysis was used to evaluate community associations among stations, sample dates, and species (ORU 1977:p. 10.1-60). Again, the channel and plume stations were similar in species composition, and the inshore station appeared to support a different fish community. The level of similarity of the stations varied seasonally and between years. The greatest similarity occurred during 1971, 1972, 1975, and 1976. There appeared to be no postoperational effect and no consistent differences between the plume station and stations outside the influence of the thermal discharge. Analysis of species associations further indicated that habitat preference may be responsible for similarities and dissimilarities among the three stations. For example, an association of hogchoker (_Trinectes maculatus_), yearling and older white perch, Atlantic tomcod, and bay anchovy inhabited the deeper water stations typical of their river-wide distribution. However, brown bullhead (_Ictalurus nebulosus_), tessellated darter (_Etheostoma olmstedi_), spottail shiner, and blueback herring appeared to prefer the shallow inshore station. McFadden (1977: p. 5.85) concluded that power plant operation has not appreciably changed the structure of the Hudson River fish community; the community appears to be diverse and resilient, responding to seasonal ambient temperatures cycles, salinity changes, and differences in natural habitat. There is no indication of a near-field or postoperational community response to the thermal plume at the Bowline Point plant.

These studies do not indicate any shift in the community structure toward one dominated by nuisance species. No species have exhibited sharp increases in abundance so as to dominate the community or reduce the successful propagation of other components of the community. As discussed above, the fish community is diverse demonstrating no substantial changes in species abundance or competitive balance as a result of the thermal discharge (and other relevant stresses) from the Bowline Point plant.

4.6.3.3 Selected Species

The species discussed individually in this section were selected because of their designation as RIS (striped bass, white perch, Atlantic tomcod, alewife, and bay anchovy), value as a commercial or sport fish (American shad and spot), or abundance in the vicinity of the Bowline Point plant (hogchoker, blueback herring). Detailed predictions of the influence of thermal discharge from the Bowline Point plant on RIS are provided in Chapter 5.

4.6.3.3.1 Striped Bass

The abundance of striped bass has been highly variable in the vicinity of the Bowline Point plant (ORU 1977:pp. 10.1-23 - 10.1-28). Much of this variability may be related to freshwater flow patterns; that is, young striped bass may seek areas of preferred salinity. Juveniles first occur in deeper channel areas near the plant in mid-June, but begin to move inshore in mid-July. Texas Instruments (1976c:p. V-17) reported a general downstream movement and concentration of juveniles in the shore zone that functioned as a nursery area throughout the summer. Maximum catch-per-unit effort of juvenile striped bass in beach seines occurred in the area of the salt intrusion, suggesting a preference for low-salinity brackish water. Highest concentrations of young-of-the-year striped bass were found from Croton-Haverstraw Bay (MP 39) to the Tappan Zee (MP 26) area; this area has extensive shoal areas bordering the deeper river channel. In late fall, as ambient river temperatures decrease from 20 C (68 F) to about 12 C (53.6 F), movement downstream and offshore to deep channel areas accelerates until no juveniles are collected in the shore zone after mid-November. McFadden (1977:p. 5.9) reported that many juveniles migrate out of the estuary in early fall, although a small population overwinters in the estuary before moving out of the river to the ocean. Thus, from late summer through late fall juvenile striped bass are involved with the Bowline Point plume because of their distribution. However, highest concentrations are associated with the littoral zone inshore of the thermal plume until offshore migrations begin in midfall. The very small cross-sectional extent and rapid dilution of the warmest area of the plume (Section 3.4) further limits exposure.

Yearling striped bass appear to migrate upstream and shoreward from the Yonkers (MP 15) area to the Cornwall (MP 57) region during the spring and summer (TI 1976c:p. V-29; McFadden 1977:pp. 6.23 - 6.26). Peak concentrations of yearling striped bass during the summer occur upstream of the Bowline Point plant between MP 39 and MP 61 with secondary peaks occurring north of MP 102. During the fall, yearlings return downstream to the Yonkers and Tappan Zee areas. Overwintering yearling and older striped bass are found in deeper channel areas of the lower estuary outside the influence of the thermal plume.

The distribution of striped bass between the channel and shore in the vicinity of the Bowline Point plant generally reflects the river-wide movement of striped bass downriver through the fall and out of the shore and shoal areas by winter. In the vicinity of Bowline Point, young and yearling striped bass exhibited a clear preference for the shallow, inshore areas during summer and fall but were not collected in these areas after the offshore fall migration to overwintering areas (ORU 1977:p. 10.1-52). This seasonal distribution indicates that striped bass are not excluded from preferred shore zone habitat by the thermal plume when ambient temperatures are maximum, nor attracted to the plume when ambient temperatures are low. Characteristic distribution and movement of striped bass among seasonally preferred habitats have continued without alteration by the Bowline Point thermal plume.

Riverwide distributional patterns and seasonal abundance shifts provide indirect evidence that the thermal discharge from the Bowline Point plant does not block the migratory routes of juvenile and older striped bass. The occurrence of peak egg and early larval abundance north of Bowline Point indicates that spawning adults are able to pass through the river region of the Bowline Point thermal plume en route to the primary spawning areas. Furthermore, since the Hudson River estuary is at its greatest width near the Bowline Point plant, and the plume in excess of 2.2 C (4 F) is limited to a very small area off the west shore (Section 3.4), a large area is available as a zone of passage.

First and second year growth rates declined for each year class of striped bass from 1968 to 1972 and then stabilized through 1975. Growth during the first season was variable and the greatest mean length for the young-of-the-year population in October occurred in 1973 and 1975; the smallest growth increment was obtained in 1972 and 1976. These patterns may be a result of biological population dynamics influenced by environmental variables (ORU 1977: p. 10.1-147) but did not appear to be related to operation of the Bowline Point plant.

Spawning adult populations enter the river in late March and April, moving primarily into the freshwater portions of the lower and middle estuary (MP 32

- MP 61) to spawn. Following spawning, the adults generally move out of the river by mid-June (TI 1976c:p. V-4). Since most gonadal development occurs outside of the river and adults only enter the river for a short period of time, it is not likely that the thermal discharge has in any way altered fecundity or reduced the reproductive success of striped bass.

Striped bass eggs are semibuoyant and are found throughout most of the estuary from early May through June. Maximum egg abundance during 1973-1975 occurred upstream of Bowline Point between MP 39 and MP 61 (McFadden 1977:pp. 6.7 - 6.15). In the Bowline Point vicinity, ichthyoplankton sampling during 1975 and 1976 detected no consistent differences in abundance between channel and shoal areas.

The abundance of striped bass larvae in the area of the Bowline Point plant was similar from 1973 to 1976. Larvae were generally present from mid-May through July; yolk-sac larvae dominated until mid-June, when post-yolk-sac larvae became the predominant life stage (McFadden 1977:pp 6.6-10; ORU 1977: p. 9.1-26). Total larval abundance was relatively high in the vicinity of the Bowline Point plant; however, peak abundance occurred just north of Bowline Point, between MP 39 and MP 55. McFadden (1977:p. 6.10) found a movement of larvae from the deeper channel stations to the shallow littoral zone beginning in mid-June and becoming more pronounced in early July as post-yolk-sac larvae mature. Larval abundance in the Bowline Point vicinity during 1973-1976 was generally lowest at the east shoal station (across the river from the plant), and highest in the channel. The Bowline Point near-field shoal station was generally intermediate (ORU 1977:p. 9.1-32). No trends in spatial distributions could be attributed to the thermal discharge.

In summary, no appreciable harm to any life stage of striped bass can be demonstrated as a result of the thermal discharge (or other related stresses) of the Bowline Point plant. Young and yearling striped bass are not excluded from the discharge area by the thermal plume when ambient temperatures are maximum, nor are they attracted to the plume during the late fall and winter, when the fish migrate to offshore overwintering areas. The potential for cold shock is therefore minimized. The plume does not block migratory routes of juvenile and older striped bass, nor does it interrupt spawning migrations. No long-term trends in growth rates have been detected that indicate any thermal effects of the Bowline Point plant. Finally, no spatial or temporal differences in egg or larval distributions have occurred that can be attributed to plant operation. Thus, the Bowline Point thermal discharge has caused no prior appreciable harm to the striped bass population of the Hudson River.

4.6.3.3.2 White Perch

White perch was one of the most abundant resident species in the vicinity of the Bowline Point plant and exhibited marked seasonal distribution and movement throughout the estuary from 1971 through 1976. McFadden (1977:pp. 6.31 - 6.35) and TI (1976c:pp. V-45 - V-49) reported that early juveniles are abundant in areas deeper than 20 ft, particularly in the channel, until mid-July when movement into the shore zone (10 ft) becomes pronounced. This shoreward movement begins first in the upper estuary and develops downriver as summer progresses. When ambient river temperature decreases in the fall to 20 C (68 F), juvenile white perch begin to move downriver and offshore into overwintering areas (greater than 20 ft) in the lower and middle estuary. Since the Bowline Point plant discharges water adjacent to the shoal area, juvenile white perch are exposed to the high isotherm areas of the plume only during movement through the shoals between the shore zone and the channel during early summer and midfall.

Yearling and adult white perch migrate upstream and shoreward as ambient river temperature increases to about 12 C (53.6 F) in the spring (TI 1977:p. V-72; TI 1976c:p. V-33). Upstream movements associated with spawning result in peak abundance of adults in fresh or brackish water north of Indian Point (MP 42) during early summer; following spawning, adults again move downstream with peak catches in areas of higher salinity from Haverstraw Bay south (TI 1976c: p. V-38; McFadden 1977:p. 5.15). Yearling white perch, like young of the year, reside in the middle and upper estuary until downriver migration in the fall. Thus, yearling white perch are present in the vicinity of the plume at the Bowline Point plant predominantly during the spring and fall migrations. However, since the population appears to be stable and egg and larval abundance and distribution have remained similar through the years, there is no indication that the thermal discharge has interfered with migration or spawning of adults. Furthermore, since a large cross-sectional area of the Hudson River remains unaffected by the thermal plume (Section 5.2) it is reasonable to conclude that no blockage to migration has occurred and that even during migration exposure to the plume is minimal.

Collections in the vicinity of the Bowline Point plant generally reflect these river-wide movement patterns of white perch (ORU 1977:p. 10.1-52). Although no consistent difference in abundance between plume and river channel (outside of the influence of the plume) occurred, movement of young of the year and yearling into the shallow shore nursery areas in the spring was observed. The late fall movement to deeper waters also occurs with no apparent preference for the warmer discharge area; consequently, the opportunity for cold shock is minimized. Furthermore, differences in local distribution were related to normal migratory behavior, not to attraction or avoidance of the plume.

Biological characteristics and population dynamics of white perch have remained fairly stable in recent years and are apparently unaffected by operation of the Bowline Point plant (ORU 1977:p. 10.1-23). Peak abundance during the 6-year period 1971-1976 occurred in 1971, 1972, and 1974 with lows in 1973 and 1976. A slight decrease in abundance determined by bottom trawl collections during this 6-year period may indicate a difference in longitudinal distribution resulting from variation in salinity and freshwater flow or natural population cycles (ORU 1977:p. 10.1-23).

Differences in mean length between discharge and control areas (ORU 1977: p. 10.1-59) and between control and far-field areas (TI 1976c:p. V-49) appear to reflect differences in movement patterns of juvenile and adult fish and are not the result of thermal effects on growth. That is, younger fish are more abundant inshore, whereas older fish move offshore and are more abundant in deeper areas. Mean length of age IV fish for each year class since 1968 has been low but relatively stable, although second year growth has been somewhat variable (ORU 1977:pp. 10.1-80 - 10.1-81). The similarity of growth rates in various areas of the river indicates that low growth rates were a river-wide population phenomenon not limited to the Bowline Point area. Furthermore, the low level of growth existed at least 4 years prior to operation of the Bowline Point plant, and no apparent change in the growth patterns of white perch have occurred since the Bowline Point plant began operation.

The time of peak gonadal maturation and spawning activity of white perch in the area of the Bowline Point plant coincided in all years, from 1971 through 1976 (ORU 1977:pp. 10.1-101 - 10.7-120). This indicates that no change has occurred between pre- and post-operational years in the reproduction cycle or time of spawning. The reproductive cycle followed a similar pattern in each year; i.e., a period of gonadal quiescence, followed by a period of increasing maturity for both sexes. Generally, most gonadal maturation occurred at low temperatures during the winter, coincident with the slow- or no-growth period as indicated by meristic data. Data analyzed in 1971, 1972, 1973, and 1975 identified no postoperational changes in age and size at which sexual maturation is achieved. In addition, ORU (1977:p. 10.1-113) found that white perch from the Hudson River exhibited what may be density-dependent fecundity values that were lower than other temperate populations of white perch. During 1971-1972 and 1975-1976 the ratio of male to female white perch was found to be 1:1. The similarity of sex ratio, age at maturity, length distribution, and fecundity between pre- and post-operational periods suggests a stable white perch population in the vicinity of the Bowline Point plant with no apparent effect of thermal discharge on growth or reproductive success.

White perch eggs are demersal and adhesive, and are found primarily in the bottom strata in the Bowline vicinity (ORU 1977:p. 9.1-6). During ichthyoplankton sampling in 1974, 1975, and 1976, the first eggs were collected consistently in mid-May. More eggs were generally collected at the shallower stations than in the channel, including a shallow station in the Bowline Point near-field area.

Concentrations of white perch larvae in the area of the Bowline Point plant fluctuated from 1973 through 1976, but larvae were generally present from early May through late July (ORU 1977:p. 9.1-12). Yolk-sac larvae were present until mid-June, when the majority of larvae had matured to the post-yolk-sac stage. The highest larval abundances were recorded in 1973 and 1975, although ORU suggested that low numbers in 1974 may be an artifact of the frequency and temporal distribution of samples. Abundance in 1976 was bimodal with an early summer decrease in abundance associated with abnormally high freshwater flow. There was no indication of lateral spatial preference for white perch larvae during 1973 through 1976 (ORU 1977:p. 9.1-12), although the channel station had the highest abundance during 1975 and 1976 peaks.

In summary, no appreciable harm to any life stage of white perch can be demonstrated to occur as a result of the thermal discharge (or other related stresses) of the Bowline Point plant. No consistent differences in abundance between plume and nonplume areas have been detected. During the summer months, temperatures within the plume area do not exclude white perch, nor are white perch attracted to the plume during late fall when the normal movement to deeper waters occurs. The latter phenomenon minimizes the potential for cold shock. No differences in growth rates between white perch collected in plume and nonplume areas have been detected, nor have any overall trends in growth rates occurred since the first operation of the plant. The similarity of sex ratio, age at maturity, length distribution, and fecundity between pre- and post-operational periods suggests a stable white perch population with no apparent effect of the Bowline Point thermal discharge on growth or reproductive success. Finally, no spatial or temporal differences in egg or larval distributions have occurred that can be attributed to plant operation. Thus, the Bowline Point thermal discharge has caused no prior appreciable harm to the white perch population of the Hudson River.

4.6.3.3.3 Atlantic Tomcod

Atlantic tomcod abundance in the Hudson River is dependent on success of the young-of-the-year population; ORU (1977:p. 10.1-28) and McFadden (1977:

p. V-13) reported that the majority of the annual catch is composed of young of the year. By the end of their first year all but the smallest tomcod in the Hudson River are sexually mature and comprise at least 87 percent of the spawning population (ORU 1977:pp. 10.1-168, 10.1-199).

Tomcod move shoreward and upstream in December and are distributed from Tappan Zee (MP 26) to Saugerties (MP 102) with peak spawning in the middle estuary near West Point (MP 52) (TI 1977:p. V-13). Spawning continues until about mid-January when post-spawners again move offshore and downstream. By May, few yearling and older fish are found in the river. Since abundance has remained relatively stable it is reasonable to conclude that the plume does not interfere with normal migration.

Juvenile tomcod are first collected in late April, concentrated near the bottom in areas of low salinity (ORU 1977:p. 10.1-29). By June, juveniles dominate all collections of tomcod in the estuary. Little or no growth occurs during the summer because of the cold water adaption of Atlantic tomcod; the seasonal pattern of growth and activity is opposite that of most other Hudson River fishes. Juvenile growth resumes in the fall when water temperatures decline, and the young approximately double their summer length by December. During this fall growth period, TI (1977:p. V-13) found that tomcod juveniles occupied the deep channel areas from Tappan Zee (MP 26) to Indian Point (MP 42). Since the thermal plume at the Bowline Point plant is essentially surface oriented and occupies a very small cross-sectional area adjacent to the shoal, exposure of the population to the plume during summer months is minimal.

The growth rate for the first year is greater than that of most other species in the river, attaining approximately 51 percent of age III length in 1 year

(ORU 1977:p. 10.1-173). First year growth rates generally declined for each year class from 1970 to 1973, then increased through 1975 with females always demonstrating a higher rate of growth than males. Growth trends were apparently influenced by physicochemical variables in the estuary but exhibited no relationship to operation of the Bowline Point plant.

According to ORU (1977:pp. 10.1-186), gonadal maturation reaches a maximum level in November for males and in late December/early January for females. No significant difference was found in the ratio of fecundity to body weight from 1972 to 1975. Furthermore, no change in the reproductive cycle and time of spawning of tomcod was found between preoperational (1971-1972) and post-operational (1973-1975) years near the Bowline Point plant. Thus, there is no apparent effect of operation of the Bowline Point plant on reproductive success of Atlantic tomcod.

Atlantic tomcod larvae generally occur in the earliest ichthyoplankton samples collected in mid-February and are presumably present from late January or early February. Yolk-sac larvae were abundant in the lower estuary from the beginning of March through April, which indicates that peak spawning was probably well above the Bowline Point plant (McFadden 1977:p. 6.42). Peak larval abundance in the vicinity of the Bowline Point plant (ORU 1977:p. 9.1-40) coincided with the river-wide peak in mid-March. During this period maximum concentrations occured near Poughkeepsie (MP 75) (McFadden 1977:p. 6.42). Abundance of post-yolk-sac larvae peaked in early April in the most downstream freshwater areas of the estuary, well below the Bowline Point plant, and tomcod larvae maintained their position relative to preferred salinity (greater than 1,000 µmho/cm) (ORU 1977:p. 9.1-40). McFadden (1977:pp. 6.42 - 6.43) reported that post-yolk-sac tomcod were more abundant in the channel than in the shoals with no apparent vertical preference by yolk-sac larvae. Older larvae showed a preference for bottom strata that became more pronounced with maturation to the early juvenile stage (ORU 1977:p. 9.1-40). Peak abundance of the early juveniles again shifted upstream to the West Point/Cornwall regions. Distribution of these early life stages of Atlantic tomcod indicates that only yolk-sac larvae are abundant in the vicinity of the Bowline Point plant plume.

Abundance of larval tomcod increased from 1974 to 1976, indicating that the population is not adversely affected during the movement of yolk-sac larvae downriver past the Bowline Point plant (ORU 1977:p. 9.1-40). This period of migration is relatively short and occurs when larvae are located primarily in the channel. Therefore, contact with the small area of the warmest plume temperatures (see Section 3.4) is negligible. Decreases in abundance between yolk-sac and post-yolk-sac larvae were consistent with natural mortality rates associated with various life stages. Consequently, it appears that the thermal discharge from the Bowline Point plant does not adversely affect early development stages of Atlantic tomcod.

In summary, Atlantic tomcod have demonstrated no trends in abundance and distribution which suggest any adverse effects from the Bowline Point thermal discharge (and other related stresses). No trends in growth rates or reproductive success have occurred which are related in any way to the thermal discharge. The spawning habits and preferred habitat of the species minimizes contact with the thermal discharge area, and therefore minimizes the potential for impact. Thus, the Bowline Point thermal discharge has caused no prior appreciable harm to Atlantic tomcod.

4.6.3.3.4 Alosa spp.

The herring family, Clupeidae, is represented in the Hudson River primarily by the genus Alosa. The three dominant anadromous species in this genus found in the vicinity of the Bowline Point plant are American shad (*A. sapidissima*), alewife (*A. pseudoharengus*), and blueback herring (*A. aestivalis*).

The major nursery areas of juvenile blueback herring during the summer were located in freshwater or brackish portions of the estuary (TI 1976c:p. V-74). Juveniles first moved into the shore zone of the middle and upper estuary in late June. By midsummer juvenile blueback herring were distributed throughout the estuary with the highest abundance north of the Bowline Point plant, from West Point (MP 52) to Albany (MP 145). Downstream and offshore movement begins as temperatures decline in midfall, and by early December most juveniles (approximately 70 mm mean length) have apparently migrated to the ocean (McFadden 1977:p. 6.48). Consequently, vulnerability of juveniles to the Bowline Point plant is limited primarily to the period of fall migration. Even during this period, exposure is limited by the relatively small size and rapid dilution of the warmest portion of the plume (Section 3.4).

Little distributional information is available for sexually mature blueback herring in the Hudson River. Blueback herring generally do not mature before 3 years of age; spawners apparently migrate up the channel to the freshwater zone of the middle estuary north of the Bowline Point plant and return to the ocean shortly after spawning(TI 1976c:pp. V-72 - V-74). Spawning probably occurs in the river in or near major tributaries. Since spawning migration occurs primarily in the channel, vulnerability to the plume is negligible and blockage of migration does not occur.

Growth rates of juvenile blueback herring were variable for year classes from 1971 through 1976; the poorest growth years were 1971 and 1972 and the best was 1974. No significant trend in growth rates was reported by ORU (1977: p. 10.1-212), although length attained by November during postoperational years, 1973 through 1976, was slightly greater than that attained during preoperational years. Since most of the growth period is spent north of the Bowline Point area, it is not likely that the slight growth increase is due to the operation of the Bowline Point plant.

Alewife juveniles move to the shore zone in freshwater areas of the estuary north of Indian Point (MP 42) during late June. As temperatures decline in midfall, juveniles move offshore and migrate downstream to the ocean by December. Sexually mature adults (TI 1976c:p. V-48) spawn in or near small feeder streams and occasionally near rocky shorelines. Spawning occurred in late April and May in the freshwater zone primarily above West Point (MP 52). Spent adults are not collected in the river after mid-June. Since alewife are primarily located north of the Bowline Point plant except during migrations, they are not generally exposed to the plume except during spring and fall. Even during migration susceptibility is limited because of the small portion of the river cross-sectional area occupied by the warmest portions of the plume.

Although the primary spawning areas of alewife and blueback herring are upstream, north of Poughkeepsie (MP 75), some eggs are found throughout the estuary (TI 1976c:pp. V-67 - V-71). Yolk-sac and post-yolk-sac larvae are concentrated in the upper estuary during their period of peak abundance (mid-May to early June). Yolk-sac larvae are not found after June, but a few post-yolk-sac larvae can still be found in mid-August.

Juvenile American shad first appear in the channel and shoals in the Tappan Zee region in mid-May (TI 1976c:p. V-58; TI 1977:p. V-15); juveniles are not collected upriver until mid-June. Juveniles appear in the shoals of the middle and upper river in late June and increase to peak abundance in early July; maximum abundance occurs between West Point (MP 52) and Poughkeepsie (MP 75). There was a gradual movement to the shore zone from mid-June through August. Abundance begins to decline during October and rapidly decreases in the late fall as juveniles migrated seaward. McFadden (1977:p. 5.27) reported that the downriver juvenile shad migration is complete by late November when fish have attained an average total length of 90 mm. American shad juveniles are therefore present in the vicinity of the Bowline Point plant plume only during the fall migration. Exposure is further limited by the small extent of the warmest portion of the plume.

Adult American shad (3-6 years old) enter the river in late March and spawn through June, principally above Hyde Park (MP 82) (McFadden 1977:p. 5.24). Exposure of adults to the Bowline Point plume is negligible and their spawning migration is not adversely affected by operation of the plant since annual abundances of shad eggs and larvae have not changed significantly.

American shad eggs are nonadhesive and semibuoyant. Since the primary spawning area is in or near the mouths of tributaries north of the Bowline Point plant, peak egg abundance occurs near Kingston (MP 91) (TI 1976c:p. V-55; TI 1977:pp. V-14 - V-15; McFadden 1977:p. 6.37). Consequently, there is virtually no exposure of shad eggs to the plume at the Bowline Point plant.

American shad yolk-sac larvae are rare below Poughkeepsie (MP 75), with peak abundance from early May through June in the channel area. Minor concentrations of yolk-sac and post-yolk-sac larvae were reported in the Croton-

Haverstraw Bay area during 1973 (TI 1976c:p. V-53), which may have been associated with some limited spawning activity in or near the Croton River. During 1974, no yolk-sac larvae were collected south of West Point (MP 52) (TI 1977:p. V-14). Post-yolk-sac shad were most abundant in June in the Poughkeepsie (MP 75)/Saugerties (MP 102) area. These distribution patterns indicate that potential exposure of the early developmental stages of American shad to the Bowline Point plant is negligible.

All three *Alosa* species appear to spawn primarily north of the Bowline Point plant, and, except during spring and fall migration, young of the year and yearlings are not exposed to the thermal plume. During these periods of migration no large concentrations of *Alosa* spp. were observed in the vicinity of the plume. Consequently, the involvement of *Alosa* spp. with the thermal plume at the Bowline Point plant appears to be negligible.

In summary, the Bowline Point thermal discharge (and other related stresses) has had little or negligible effect on *Alosa* spp. populations because of minimal exposure owing to upstream spawning, early development, and residence, except during spawning and seaward migrations. During migrations, exposure is minimized by the small size of the high isotherm portions of the thermal plume in relation to the river width and cross-sectional area. The late-fall seaward migration of juvenile *Alosa* spp. and the lack of overwintering populations minimizes the potential for cold shock. Thus, the Bowline Point plant has caused no appreciable harm to Hudson River *Alosa* spp. populations.

4.6.3.3.5 Bay Anchovy

Bay anchovy are predominantly single age-class spawners and show large oscillations in abundance (ORU 1977:p. 10.1-31). This variability is influenced by the flow of freshwater and the extent of saltwater intrusion into the Bowline Point area. The highest densities generally occur in the more saline Yonkers (MP 15) and Tappan Zee (MP 27) region south of the Bowline Point plant, although TI (1976c:p. V-107) reported that adults were taken in the channel as far upriver as the Cornwall region from mid-May through October in 1973. Peak collections in the Croton-Haverstraw Bay area occur in August and were primarily composed of juveniles. Abundance declines sharply in the fall as juveniles migrate to the ocean when the salt front recedes and temperatures decline. Because of the shift in bay anchovy abundance with the salt front, involvement with the plume at the Bowline Point plant is intermittent. When juveniles and adults are in the area, exposure is limited by the small extent of the warmest area of the plume.

Available data indicate no apparent growth trend for bay anchovy related to the operation of the Bowline Point plant (ORU 1977:p. 10.1-214). At the end of the growing season, the average total length attained was lowest in 1971, highest in 1972, and fluctuated at an intermediate level during the post-operational years of 1973 through 1975. Bay anchovy spawn from early June to September. Spawning occurs south of the salt front with peak areas in 13-15 ppt salinity (ORU 1977:p. 9.1-62). Eggs are buoyant but become progressively demersal with development. Sharp shifts in abundance and relatively low abundance during 1974-1976 in the area of the Bowline Point plant appeared to be related to changes in freshwater flow and salt-front location. The larvae had an apparent preference for shallow areas rather than the channel during 1975 and 1976. However, because of the relationship between high salinity and distribution, and the limited extent of the warmest area of the plume, exposure of bay anchovy eggs and larvae to the Bowline Point plant thermal plume is expected to be intermittent and negligible.

4.6.3.3.6 Hogchoker

The hogchoker (Trinectes maculatus) was the only major species in the Bowline Point plant area that exhibited a consistent trend of increasing abundance from 1971 through 1976 (ORU 1977:p. 10.1-31). Hogchokers were most abundant near the bottom in shoal and channel areas. Adult distribution is partially related to salt-front position; adults spawn during July in higher salinity water (approximately 10 ppt) (TI 1976c:p. V-177). After spawning, adults migrate upstream in late summer to areas of low salinity (ORU 1977:p. 10.1-35). As the salt front recedes downstream in the fall, high concentrations of adult hogchoker move into the deep channel areas in the Indian Point and Croton-Haverstraw Bay area (MP 34-46) near the saltwater/freshwater interface. Adult hogchoker are abundant in the area of the Bowline Point plant primarily during the summer. However, since they are primarily demersal and the plume has little contact with the bottom, involvement with the plume is negligible.

Juveniles were first collected during August (TI 1976c:p. V-179). Their distribution extends from the Yonkers to Cornwall area (MP 14-61), but greatest concentrations occur in the Tappan Zee region (MP 24-33) downstream of the Bowline Point plant. During fall, catches progressively increase in the Indian Point region (MP 39-46) as juveniles migrate into this area to overwinter in the deeper channel waters (TI 1976c:p. V-181). Although relatively abundant in the vicinity of the Bowline Point plant from late summer through fall, exposure is minimal since, like adults, juveniles are primarily demersal.

4.6.3.3.7 Spot

The spot (Leiostomius xanthurus) is a commercially important fish in the middle and southern Atlantic states and an occasional marine migrant in the

Hudson River estuary. ORU (1977:p. 10.1-43) reported that spot have been collected in the Hudson River estuary from 1973 through the present, although they had not been previously reported in the river since 1896. Spot move into the saline sections of the estuary during the summer and ranked sixth in abundance in the vicinity of the Bowline Point plant during 1976; this reoccurrence is apparently uninhibited by the thermal discharge from the Bowline Point plant.

4.7 OTHER VERTEBRATE WILDLIFE

The effects of the thermal discharge of the Bowline Point plant on vertebrate wildlife other than fish are considered to be of "low potential impact" because the plume does not impact large or unique populations of wildlife, nor do any threatened or endangered species of wildlife occur in the Bowline Point area. The plume does not attract migratory waterfowl or encourage them to remain in the area through the winter. Furthermore, as has been demonstrated previously in this chapter, the effect of plant operations on other biota on which birds feed (e.g., benthic invertebrates and aquatic vegetation) has not been significant. It is therefore concluded that the thermal discharge will not affect wildlife.

CHAPTER 4: REFERENCES

Boesch, D. F., M. L. Wass, and R. W. Virnsteine. 1976. The dynamics of estuarine benthic communities. In Estuarine processes. Vol. I. Uses, stresses, and adaptation to the estuary, M. Wiley (Ed.). Academic Press, New York. 541 pp.

Boyce Thompson Institute. 1973. Second Annual Report to Rockefeller Foundation. 1 May 1972 - 20 April 1973. Report No. RF71023.

Central Hudson Gas & Electric Corporation (CHG&E). 1977. Roseton Generating Station: Near-field effects of once-through cooling systems operation on Hudson River biota.

Consolidated Edison Company of New York, Inc. 1977. Indian Point Unit No. 2, Indian Point Unit No. 3, Near-field effects of once-through cooling system operation on Hudson River biota.

Ecological Analysts, Inc. (EA). 1977a. Bowline Point Generating Station entrainment and impingement studies. 1976 Annual Report. Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. (EA). 1977b. The effects of intakes and associated cooling water systems on phytoplankton and aquatic invertebrates of the Hudson River. Central Hudson Gas & Electric Corporation, Consolidated Edison Company of New York, Inc., Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. (EA). 1978a. Final report, Hudson River thermal effects studies for representative species. Prepared for Central Hudson Gas & Electric Corporation and Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. (EA). 1978b. Thermal life history literature review for Hudson River representative important species. Prepared for Central Hudson Gas & Electric Corporation, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. (EA). 1978c. Field studies of the effects of thermal discharges from the Roseton and Danskammer Point Generating Stations on Hudson River fishes. Prepared for Central Hudson Gas & Electric Corporation.

Ginn, T. C. 1977. An ecological investigation of Hudson River macrozooplankton in the vicinity of a nuclear power plant. Ph.D. Dissertation. New York University, March.

Greeley, J. R. 1937. Fishes of the area with annotated list. In A Biological Survey of the Lower Hudson Watershed, E. Moore (Ed.). NYSCD:45-124.

Hansen, D. V. 1967. Salt balance and circulation in partially mixed estuaries. In Estuaries, G. H. Lauf (Ed.). AAAS Publ. No. 83. pp. 45-51.

Heffner, R. L. 1974. Phytoplankton community dynamics in the Hudson River Estuary between mile points 39 and 177. Proc. of the Third Hudson River Symposium. Bear Mountain, New York. Paper No. 17.

Heinle, D. R. 1974. An alternative grazing hypothesis of the Patuxent Estuary. Chesapeake Sci. 15(3):146-150.

Hulsizer, E. E. 1976. Zooplankton of lower Narragansett Bay. Chesapeake Sci. 17(4):260-270.

Lauer, G. J., W. T. Waller, D. W. Bath, W. Meeks, R. Heffner, T. Ginn, L. Zubarik, P. Bibko, and P. C. Storm. 1974. Entrainment studies on Hudson River organisms. Proceedings of the Second Entrainment Workshop and Intake Screening Workshop. The Johns Hopkins University Cooling Water Research Project, Report No. 15, December.

Lawler, Matusky & Skelly Engineers (LMS). 1974a. 1973 Hudson River aquatic ecology studies at Roseton and Danskammer Point. Report to Central Hudson Gas & Electric Corporation, October.

Lawler, Matusky & Skelly Engineers (LMS). 1974b. 1973 Hudson River aquatic ecology studies - Bowline Point and Lovett Generating Stations. Report to Orange and Rockland Utilities, Inc. December.

Lawler, Matusky & Skelly Engineers (LMS). 1975a. 1974 Hudson River aquatic ecology studies at Roseton and Danskammer Point. Central Hudson Gas & Electric Corporation.

Lawler, Matusky & Skelly Engineers (LMS). 1975b. 1973 Hudson River aquatic ecology studies at Kingston, New York. Central Hudson Gas & Electric Corporation.

Lawler, Matusky & Skelly Engineers (LMS). 1975c. 1974 Hudson River aquatic ecology studies--Bowline Point and Lovett Generating Stations. Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers (LMS). 1976. 1975 Hudson River aquatic ecology studies - Bowline Point and Lovett Generating Stations. Vol. 1, 1-1X. LMSE-76/051 and 169/105.

McFadden, J. T. 1977. Influences of Indian Point Unit 2 and other steam electric generating plants on the Hudson River estuary, with emphasis on striped bass and other fish populations. Submitted to Consolidated Edison Company of New York, Inc.

Muenscher, W. C. 1936. Aquatic vegetation of the lower Hudson area. In A Biological Survey of the Lower Hudson Watershed, E. Moore (Ed.). NYSCD.

New York University Medical Center (NYU). 1974. Effects of entrainment by the Indian Point Power Plant on Hudson River estuary biota. Progress report for 1973. Prepared for Consolidated Edison Company of New York, Inc.

New York University Medical Center (NYU). 1975. Effects of entrainment by the Indian Point Power Plant on Hudson River estuary biota. Progress report for 1974. Prepared for Consolidated Edison Company of New York, Inc.

Orange and Rockland Utilities, Inc. (ORU). 1977. Bowline Point Generating Station: Near-field effects of once-through cooling systems operation on Hudson River biota.

Patrick, R. 1969. Some effects of temperature on fresh-water algae. In Biological Aspects of Thermal Pollution. Vanderbilt Univ. Press.

Ristich, S. S., M. Crandall, and J. Fortier. 1977. Benthic and epibenthic macroinvertebrates of the Hudson River. I. Distribution, natural history and community structure. Estuarine Coast. Mar. Sci. 5:255-266.

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. of Canada, Bull. 184. 966 pp.

Storm, P. C. and R. L. Heffner. 1976. A comparison of phytoplankton abundance, chlorophyll a, and water quality factors in the Hudson River and its tributaries. Proc. of the Fourth Hudson River Symposium. Bear Mountain, New York. Paper No. 17. 39 pp.

Texas Instruments, Inc. (TI). 1975a. Hudson River ecological study in the area of Indian Point. 1974 Ann. Rep. Consolidated Edison Company of New York, Inc.

Texas Instruments, Inc. (TI). 1975b. Benthic landfill studies, Cornwall. Final Rep. Consolidated Edison Company of New York, Inc.

Texas Instruments, Inc. (TI). 1975c. Hudson River environmental study in the area of Ossining. Final Rep. Consolidated Edison Company of New York, Inc.

Texas Instruments, Inc. (TI). 1976a. Hudson River ecological study in the area of Indian Point. 1975 Ann. Rep. Consolidated Edison Company of New York, Inc. December.

Texas Instruments, Inc. (TI). 1976b. A synthesis of available data pertinent to major physiochemical variables within the Hudson River estuary. Submitted to Consolidated Edison Company of New York, Inc.

Texas Instruments, Inc. (TI). 1976c. Fisheries survey of the Hudson River, March-December 1973. Vol. IV. Revised ed. Consolidated Edison Company of New York, Inc. June.

Texas Instruments, Inc. (TI). 1977. 1974 year-class report for the multiplant impact study of the Hudson River estuary. Vol. I. Consolidated Edison Company of New York, Inc.

United States Environmental Protection Agency (EPA). 1977. Draft Interagency 316(a) Technical Guidance Manual and Guide for Thermal Effects Sections of Nuclear Facilities Environmental Impact Statements. Washington, D.C. 79 pp.

Chapter 5
REPRESENTATIVE IMPORTANT SPECIES RATIONALES

CHAPTER 5: REPRESENTATIVE IMPORTANT SPECIES RATIONALES

5.1 INTRODUCTION

This chapter predictively evaluates whether the present Bowline Point Generating Station thermal discharge will reasonably assure the protection and propagation of a balanced indigenous community of shellfish, fish, and wildlife in and on the Hudson River. The method employed is to evaluate the potential for adverse effect of the thermal discharge on representative important species (RIS). These RIS were designated by the EPA (Subsection 1.2.2) as representative of the balanced indigenous community of shellfish, fish, and wildlife in and on the Hudson River estuary. Included in the RIS evaluations are the potential for mortality from cold shock; mortality from excess heat; reduced reproductive success or growth as a result of plant discharges; loss of available habitat within the discharge area owing to high temperatures; and blockage of migrations. Evaluations are based on hydrothermal data, plant operational data, and species-specific life history and thermal effects data.

For purposes of illustration, thermal effects diagrams are presented for each RIS. These diagrams contain an integration of information on the occurrence of each life stage in the vicinity of the plant, ambient water temperature, discharge temperature, and thermal effects data. These integrated data are used to evaluate potential thermal effects produced by contact of each life stage with the thermally altered area.

The arguments supporting the assertion that the selected RIS will suffer no appreciable harm from the heated discharge of the Bowline Point plant are presented in Section 5.2. The data supporting these arguments are presented in Section 5.3 for the following RIS: striped bass, white perch, Atlantic tomcod, alewife, white catfish, spottail shiner, Atlantic stugeon and shortnose sturgeon, bay anchovy, weakfish, *Neomysis americana*, *Crangon septemspinosa*, and *Gammarus* spp.

5.2 RIS RATIONALE

The combination of an offshore location and a high-velocity diffuser design for the Bowline Point plant cooling water discharge structure minimizes the potential for appreciable harm to populations of selected representative important species (RIS) of fish and macroinvertebrates. Because of the discharge location and design, thermal plume temperatures exceeding 4.3 C (7.7 F) above ambient are limited to a small space in the immediate discharge vicinity (Section 3.4.2). Within that space, diffuser current velocities exceed 4 fps and thereby exclude the extended residence of fish and macroinvertebrates. Thus, the maximum plume isotherm above ambient to which aquatic organisms may be exposed for more than 5-10 seconds is 4.3 C (7.7 F).

No appreciable harm resulting from entrainment into the thermal plume of the Bowline Point plant is expected for any RIS. Because of the rapid dilution of cooling waters upon passing through the diffuser ports, plume entrainment exposures to full delta-Ts are limited to a few seconds. As a result, the potential for plume entrainment heat shock mortality is minimal. A review of the short-exposure thermal tolerance of each of the RIS, extensively documented in Section 5.3, has shown that most species are capable of tolerating even the warmest plume temperatures for periods of time (5-30 minutes) far in excess of actual exposure duration at the diffuser. Furthermore, since actual exposure to peak discharge temperatures is limited to 5-10 seconds, no mortality is expected even for those species whose thermal tolerance limits to exposures of 5-30 minutes were exceeded by the maximum discharge temperatures.

The thermal discharge from the Bowline Point plant does not result in the loss of any major habitat for aquatic organisms that normally occur in areas influenced by the thermal plume. A review of the avoidance responses and temperature requirements for survival of juvenile and adult life stages of the RIS, extensively documented in Section 5.3, has shown that in most cases the RIS are capable of tolerating plume temperatures up to 4.3 C (7.7 F) above ambient. The noted exception was for Atlantic tomcod juveniles. However, the preference of this species for deeper, cooler, channel areas of the river precludes any adverse impact from the predominately surface-oriented thermal plume.

A review of the data available on the effects of elevated temperatures on early development, as documented in Section 5.3, has indicated that for most RIS, temperatures up to 4.3 C (7.7 F) above ambient will have no adverse effects on normal hatching success. One exception was noted for the winter spawning Atlantic tomcod. Eggs of this species cannot tolerate extended exposures to temperatures above approximately 5 C (41 F). However, since few Atlantic tomcod eggs are found in the Bowline Point vicinity due to the fact that the predominant spawning area is located upstream, and since eggs are demersal and adhesive and do not come in contact with higher plume isotherms found near the surface, the actual impact of the plant is neglible.

The effects of elevated temperatures on growth and performance of the RIS are also extensively documented in Section 5.3. The temperature ranges for optimum growth for many RIS are exceeded during some months by the maximum discharge temperature. However, since high velocities in the immediate vicinity of the discharge prevent extended exposures to temperatures exceeding 4.3 C (7.7 F) above ambient, the potential for adverse effects on growth and development of aquatic organisms is substantially minimized. The temperature range for optimum growth usually exceeds river ambient temperatures, particularly for the young fish. Juvenile Atlantic tomcod again is an exception, since even the lower plume temperatures exceed optimal growth during the summer months. However, the preference of this species for cooler, bottom, channel areas precludes the potential for adverse impact. A similar situation exists for weakfish juveniles during summer months. Thus, the thermal discharge of the Bowline Point plant should have no adverse effects on the growth of RIS residing in or migrating through the discharge vicinity.

The effects of the thermal discharge on reproduction are also evaluated in Section 5.3. Because of rapid dilution of the discharge waters and the small size of the thermal plume in relation to the river surface width and cross-sectional area, there exists no evidence that spawning migrations of anadromous species (such as striped bass, alewife, and Atlantic tomcod) are blocked or interrupted by the thermal plume. The fact that these species have successfully migrated into upstream spawning areas during the past few years is evidence that the thermal plumes of existing plants have not blocked nor interrupted migrations. Those species that may spawn to some extent in the Bowline Point vicinity are not likely to be adversely affected by the thermal plume because of its minimal extent. Thus, the Bowline Point plant's thermal discharge should not appreciably harm the balanced indigenous community through the disturbance of normal spawning activities.

The potential for cold shock mortality in the event of a total plant shutdown during the winter months is minimized by the design and location of the discharge whereby high velocities prevent fish or macroinvertebrates from residing in waters greater than 4.3 C (7.7 F) above ambient. Thus, the maximum temperature drop potentially suffered during a shutdown would be 4.3 C (7.7 F). All of the RIS, for which cold shock data are available, are capable of tolerating temperature drops in excess of 4.3 C (7.7 F) to temperatures in many cases as low as 0-2 C (32.0-35.6 F). Thus, the potential for cold shock mortality, if it exists at all, would be limited to the months of January to March when ambient temperatures are below 2 C (35.6 F). During this period, densities of those RIS that could be potentially affected by cold shock in the Bowline Point discharge vicinity are very low or negligible; no concentrations of any RIS in the thermal plume during the late fall or winter months have ever been detected. Therefore, considering both thermal effects and life history factors, the actual cold shock potential at Bowline Point is minimal. Because of the low probability of both units of the Bowline Point plant incurring an outage at the same time (this occurred two times during January-March 1975, five times during the same period in 1976, and not at all in 1977), the potential for cold shock is further limited.

In conclusion, the maximum percentages of river surface width and cross-sectional area within the 2.2 C (4 F) temperature rise isotherm of the Bowline Point plant's thermal plume were 7.9 percent and 5.5 percent, respectively, as measured during field thermal surveys conducted at near-maximum plant capacity (Subsection 3.3.1.1, Table 3.3-1). These percentages are well within the New York State thermal criteria. Because of the small area encompassed by the 2.2 C (4 F) isotherm, the predominantly surface-oriented nature of the plume, and the constant shifting of the the thermally elevated areas with tidal currents, the cooling water discharge from the Bowline Point plant is not expected to exclude any significant areas of potential habitat for aquatic organisms occurring in the vicinity of the plant. Thus, the protection and propagation of the balanced indigenous community is assured.

5.3 SUPPORTIVE RIS THERMAL EFFECTS DATA

5.3.1 Introduction

The potential effects of the Bowline Point plant thermal discharge on RIS are evaluated for five thermal effects categories as recommended in the 1 May 1977 and 30 September 1974 drafts of the EPA 316(a) Technical Guidance Manual:

1. Temperature requirements for survival of juveniles and adults.
2. Minimum avoidance temperature.
3. Temperature requirements for early development.
4. Optimum temperature for performance and growth.
5. Thermal shock tolerance.

Thermal effects parameters used in the evaluations are described according to each thermal effects category in the next subsection.

5.3.2 Thermal Effects Parameters

5.3.2.1 Temperature Requirements for Survival of Juveniles and Adults

The upper limit of the temperature range permitting survival of juveniles and adults during all seasons is evaluated to identify areas and volumes of the thermal plume that are not habitable by these life stages because of excessive temperature. Mortality would not be expected to occur within these areas since most mobile macroscopic organisms actively avoid temperatures which cause stress (EA 1978a:pp. 3-8, 4-5). The primary thermal effects parameter used for this evaluation is the upper incipient lethal temperature as estimated by 96-hour TL50s. These upper incipient lethal temperatures represent the highest temperature at which an organism can survive for "indefinite" time periods. For some species, 24- or 48-hour TL50s are used in lieu of 96-hour TL50s when the longer exposure test results are not available.

These thermal effects parameters have limited relevance to the Bowline Point plume because fish are excluded by high velocity from maintaining residence in plume temperatures more than 4.3 C (7.7 F) above ambient. In addition, the portion of the plume between 4.3 C (7.7 F) and 2.2 C (4 F) is quite small and does not remain within a given area for extended time periods because of the constant shifting of the thermal plume with the tidal currents and the wind. Therefore, fish would not be expected to reside in the warmer portions of the plume for extended periods of time.

5.3.2.2 Minimum Avoidance Temperature

Avoidance temperatures also define areas of the thermal plume which are potentially excluded as available habitat because of high temperatures. A review of the literature has revealed that in most cases aquatic organisms avoid temperatures equal to or slightly lower than incipient lethal temperatures (EA 1978a). This thermal effects parameter has limited relevancy to the Bowline Point plant's thermal plume because of the exclusion of mobile organisms from the highest elevated temperature regions of the plume as a result of the high velocity discharge currents created by the diffuser.

5.3.2.3 Temperature Requirements for Early Development

Temperature requirements for early development define zones of the thermal plume which may be suitable for successful spawning and early development, but are not available for these activities because of the elevated temperatures. Life stages addressed under this biological criterion are eggs, larvae, and early juveniles. Thermal effects parameters used for thermal effects evaluations are optimum temperature range for the normal hatch of eggs (continuous exposure) and 24-hour TL50s or ultimate upper incipient lethal temperatures for larvae and early juveniles. The upper limit of the optimum temperature range for hatch is an estimate of the maximum temperature for normal embryonic development, and is used to identify areas of the discharge that are not suitable for successful spawning because of high temperatures. Ultimate incipient lethal temperatures and 24-hour TL50s for larvae and early juveniles are used to identify areas of the discharge that are potentially unsuitable as nursery areas as a result of the plume.

These thermal effects parameters are not relevant to some early life stages of RIS because of their planktonic nature. Planktonic eggs and larvae passing through the Bowline Point plant thermal plume would not be exposed to high temperatures for anywhere near the duration of continuous exposures used to obtain temperature requirements for early development. Furthermore, nonplanktonic life stages would not be expected to be continuously exposed to even lower isotherm areas of the thermal plume because of the constant shifting of the thermal plume within the tidal currents.

5.3.2.4 Optimum Temperature for Performance and Growth

The upper temperature limit of the optimum temperature range for physiological activities can be used as an estimator of the thermal discharge zones which will permit optimum physiological functions. Temperatures above this limit would result in less than optimum functions. Thermal effects parameters used to estimate this limiting temperature are the optimum temperature range for growth, where available, and estimates of final temperature preferenda. The final preferendum is generally accepted as a good estimator of the optimum temperature for performance (Brett 1971; Coutant 1975:pp. 2-7; EA 1978b).

Thermal effects evaluations based on final preferenda may be somewhat conservative, however, since final preferenda estimates a temperature within the optimum range for performance, rather than the upper temperature limit of the optimum range. The optimum temperature range for growth is available for the larvae and/or early juveniles of a number of RIS, and final preferenda are available for juveniles and adults of most RIS. These parameters are used to estimate whether there are plume areas or volumes exceeding optimum temperature conditions for growth for each RIS. However, these thermal effects parameters are of limited relevance to the Bowline Point plume because of the rapid rate of induced dilution caused by the diffuser discharge and the fact that prolonged residence of fish in the warmer elevated temperatures near the diffuser is precluded by coincident velocities in excess of 4 fps.

5.3.2.5 Thermal Shock Tolerance

Thermal shock can occur in two ways:

1. Cold shock - aquatic organisms residing in elevated temperatures within the thermal plume are subject to cold shock in the event of a plant outage.
2. Heat shock - aquatic organisms are subject to rapid rises in temperature upon being entrained into the thermal discharge plume (plume entrainment).

Both of these thermal shocks have the potential to cause mortality if the change in temperature exceeds the tolerance of the aquatic species. Therefore, the highest temperature limit resulting in no appreciable mortality is identified for estimating these thermal effects. Thermal effects parameters used for assessing or predicting the effects of thermal shock are lower incipient lethal temperatures for cold shock and short-exposure upper thermal tolerance limits for plume entrainment shock.

Lower incipient lethal temperatures are estimated by 96-hour TL50s derived from experiments wherein warm-acclimated organisms are subjected to rapid drops in temperature and are subsequently held for 96 hours. A 2 C (3.6 F) safety factor is added to the lower 96-hour TL50s to provide estimates of lower safe levels. Since the highest plume temperature at which organisms can remain long enough to become acclimated is 4.3 C (7.7 F) above ambient, the potential for cold shock to occur at the Bowline Point plant is substantially minimized. Moreover, the presence of two units at Bowline Point further reduces the potential for cold shock because of the reduced likelihood of simultaneous shutdowns of both units.

The potential for mortality resulting from plume entrainment is predicted for planktonic organisms based on 5-, 10-, and 30-minute TL95s. The highest temperature resulting in no appreciable mortality (threshold lethal temperature) is estimated by these TL95s for each exposure duration. A TL95 is the thermal tolerance limit resulting in 95 percent survival at that temperature after continuous exposure for the specified duration. Since only a very small percentage of the planktonic organisms that pass through the Bowline Point plant's thermal plume are exposed to the maximum discharge temperatures, and exposures to temperatures greater than 4.3 C (7.7 F) above ambient last for only a few seconds, thermal effects evaluations based on 5-, to 30-minute TL95s overestimate the actual potential for mortality.

5.3.3 Elements of the Thermal Effects Evaluations

5.3.3.1 Introduction

Thermal effects evaluations for each biological criterion are accomplished by integrating thermal effects data, life history data, and hydrothermal characteristics of the thermal plume during peak operation of the Bowline Point plant. Estimates of plume areas and volumes with temperatures in excess of the temperature limits defined for RIS according to each important biological activity are presented in tabular form to fulfill information requests in the 1 May 1977 draft of the EPA 316(a) Technical Guidance Manual. Thermal effects data are presented in thermal effects diagrams for each species, which visually relate the occurrence of each life stage in the vicinity of the plant to potential thermal effects produced by contact of that life stage with the thermally altered area.

Life history data are used to predict the susceptibility of each life stage of RIS to potential thermal effects from the Bowline Point plant's cooling water discharge. Habitat requirements, spawning temperatures and dates, life cycles, spawning migrations, and normal movement and distribution patterns within the estuary determine the potential for contact of each life stage with the thermally altered area. Life history elements for each RIS are reviewed in EA (1978a), and extensively discussed for selected RIS in McFadden (1977). The seasonal distribution of each species and life stage has been included in the thermal effects diagrams so that the potential for thermal effects at any given time may be compared with the actual occurrence of the organisms at the plant site. The seasonal distributions of fish were determined from fishery surveys at river miles 36-37 between 1974 and 1976 (TI 1975a; 1976a; 1976b; 1976c; 1977) and from impingement collections between 1973 and 1976 (ORU

1977). Seasonal abundance of macrozooplankton were derived from near-field data collected between 1973 and 1976 (ORU 1977). Specific data used in generating seasonal distributions in the thermal effects diagrams are indicated in each diagram key.

Thermal effects data used for evaluations are predominantly based on research conducted by EA (1978b), TI (1976d), and NYU (1973; 1974; 1976; 1977). Supplemental thermal effects data are drawn from the general literature as reviewed and summarized by EA (1978a). Terminology used to present thermal effects evaluations in this chapter are also defined in EA (1978a:pp. 2-1 - 2-7). A discussion of the specific elements of the thermal effects evaluations, including development of the thermal effects diagrams and summary tables, is presented in the following subsections.

5.3.3.2 Hydrothermal Parameters

5.3.3.2.1 Ambient Temperature Profile

The foundation for the thermal effects diagram is the ambient temperature profile at the power plant site (Figure 5.3-1). The ambient temperature record used was that presented in Subsection 3.1.3.2 (Table 3.1-4, Figure 3.1-5)--the 10-year mean monthly average ambient temperatures recorded at Peekskill, New York, from 1959 to 1969. These 10-year monthly mean temperatures were plotted on thermal effects diagrams to produce a seasonal temperature curve. The thermal effects diagrams thus constructed relate the seasonal distribution of each species or life stage at the plant site to normal seasonal temperatures. To address potential thermal effects during exceptionally warm years (i.e., extreme ambients), the maximum monthly average temperatures recorded by USGS (Peekskill 1959-1969) and by LMS (1978) (Bowline Point near-

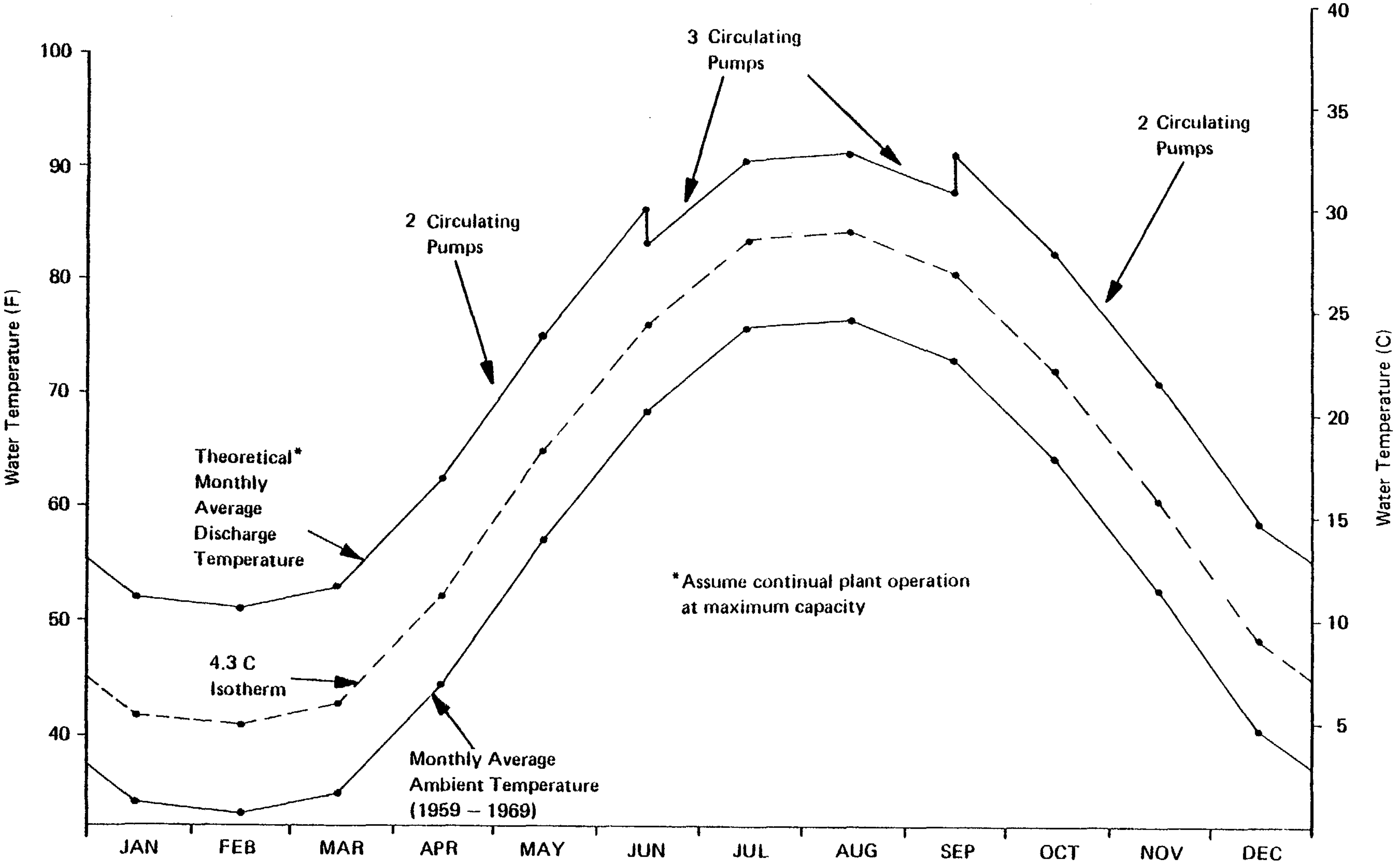


Figure 5.3-1. Example of hydrothermal elements included in thermal effects diagrams for the Bowline Point plant.

field data 1973-1976) were evaluated (Subsection 3.1.3.2; Table 3.1-6 and Figure 3.1-5).

5.3.3.2.2 Maximum Discharge Temperature Profile

In order to provide an estimation of maximum likely discharge temperatures, full-load condenser temperature rises (delta-Ts) for the Bowline Point plant were added to the ambient temperature profile (Subsection 3.2.4; Table 3.2-2 and Figure 3.2-5). Although the plant seldom operates at full load (Subsection 3.2.5), maximum possible delta-Ts were selected in order to be conservative. The maximum delta-Ts employed were 10.0 C (18.1 F) during two-pump operation and 8.2 C (14.8 F) during three-pump operation (Subsection 3.2.4). The discharge temperature profile so derived was superimposed onto the ambient temperature profile, as shown in Figure 5.3-1. The temperatures plotted represent the maximum possible discharge temperatures based on monthly average ambient river temperatures and assume continued plant operation at full capacity.

The theoretical maximum discharge temperature based on the normal ambient temperature regime is plotted on the thermal effects diagrams along with the ambient seasonal temperature curve. A reduction in the maximum discharge temperature curve is depicted during summer months and results from the increase in the volume of cooling water with three circulating pumps in operation. Potential thermal effects are predicted acording to theoretical maximum discharge temperature during both normal and unusually warm years, and are presented in thermal effects summary tables.

5.3.3.2.3 The 4.3 C (7.7 F) Isotherm

Also shown on Figure 5.3-1 is the 4.3 C (7.7 F) temperature rise isotherm. In Subsection 3.3.1.4 it was shown that at temperature elevations above 4.3 C (7.7 F) discharge current velocities exceeding 4 fps prevailed. A review of critical swim speed data for Hudson River fishes (Subsection 3.4.2; Table 3.4-1) indicated that velocities exceeding 4 fps are unlikely to be continuously negotiated by most fish. Velocities in excess of 4 fps extend outward approximately 20-40 ft from the diffuser ports (Subsection 3.4.2; Figure 3.4-1), and occur within a volume of less than 3.0 acre-ft. The 4.3 C (7.7 F) isotherm is displayed on the thermal effects diagrams to indicate the maximum temperature above which fish will be excluded as a result of velocity alone. Under most conditions the maximum habitable isotherm will actually be less than 4.3 C (7.7 F) (Subsection 3.3.1.4).

5.3.3.2.4 Calculation of Plume Areas and Volumes Exceeding Temperature Requirements

Table 5.3-1 summarizes the largest observed volumes and surface areas associated with isotherms greater than 1.7 C (3 F) for thermal plume surveys conducted at near-capacity plant operation. These data are used to identify maximum areas of the thermal plume from which important biological activities would potentially be excluded or impaired by elevated temperatures. The maximum areas, volumes, and percentage of near-field area and volume exceeding the temperature limit for important biological activities are presented in the thermal effects evaluation summary tables for each RIS.

TABLE 5.3-1 CALCULATION OF MAXIMUM THERMAL PLUME AREAS AND VOLUMES FOR ISOTHERMS GREATER THAN 1.7 C (3.1 F)(a)

Season	Temp. Rise Isotherm (>C)	Surface Area (Acres)	Percent Near-Field Surface Area	Volume (Acre-ft)	Percent Near-Field Volume(b)
Fall(c)	1.7 (3 F)	141.0	1.995	604.0	0.410
Winter	2.2 (4 F)	50.5	0.714	170.0	0.116
Spring	2.8 (5 F)	7.4	0.104	26.4	0.018
	3.3 (6 F)	0.6	0.007	1.4	0.001
	>3.3 (6 F)	<0.6	<0.007	<1.4	<0.001
Summer(d)	1.7 (3 F)	29.4	0.415	321.0	0.281
(15 June-	2.2 (4 F)	10.1	0.143	113.0	0.077
15 Sept)	2.8 (5 F)	3.7	0.052	32.10	0.022
	3.3 (6 F)	0.7	0.010	2.99	0.0020
	>3.3 (6 F)	<0.7	<0.010	<2.99	<0.0020

(a) From Subsection 3.3.1.1, Table 3.3-2.

(b) Based on a near-field area calculated as two tidal excursions (ebb and flood), one upstream (1.9 miles), and one downstream (3.6 miles); surface area of this near-field area = 7,067 acres, and volume = 146,987 acre-ft.

(c) 93.8 percent plant capacity, two-pump throttled operating mode.

(d) 93.3 percent plant capacity, three-pump operating mode.

Note: Acre = 209 ft x 209 ft (slightly smaller than a football field).
Acre-ft. = 35.2 ft x 35.2 ft x 35.2 ft (a football field covered with 1 ft of water).

5.3.3.3 Thermal Effects Parameters

For each species, thermal effects evaluation summary tables relate potential effects according to each biological criteria to areas and volumes of the plume that exceed the temperature limits during both normal and unusually warm years. Applicable thermal effects data, as available, are plotted on the thermal effects diagram to indicate predicted effects resulting from potential contact of RIS with the thermally altered area. Once the hydrothermal profile has been established, the thermal effects parameters discussed in Subsection 5.3.2 are then plotted. Examples are shown in Figure 5.3-2.

The points marked number 1 on Figure 5.3-2 represent upper incipient lethal temperatures estimated by 96-hour TL50. These are plotted directly above the point in the ambient temperature profile equivalent to the acclimation temperature at which the TL50 was determined. When the acclimation temperature exceeds the highest ambient temperature, the TL50 is plotted directly above the highest ambient temperature. Where possible, tolerance limits are plotted according to the time of the year the test was performed (i.e., tolerance limits for tests performed during the spring are plotted above the corresponding acclimation temperature during rising river temperatures, while those tolerance limits for tests performed during the fall are plotted above the corresponding acclimation temperature during falling river temperatures). For some species, data for all seasons was not available, and thermal tolerance limits were plotted above the corresponding acclimation temperature during both rising and falling river temperatures.

Once a TL50 is plotted, the plume isotherm passing through the point may be visually determined from the diagram. The area and volume enclosed by that isotherm are then determined from Table 5.3-1. When a TL50 falls above the

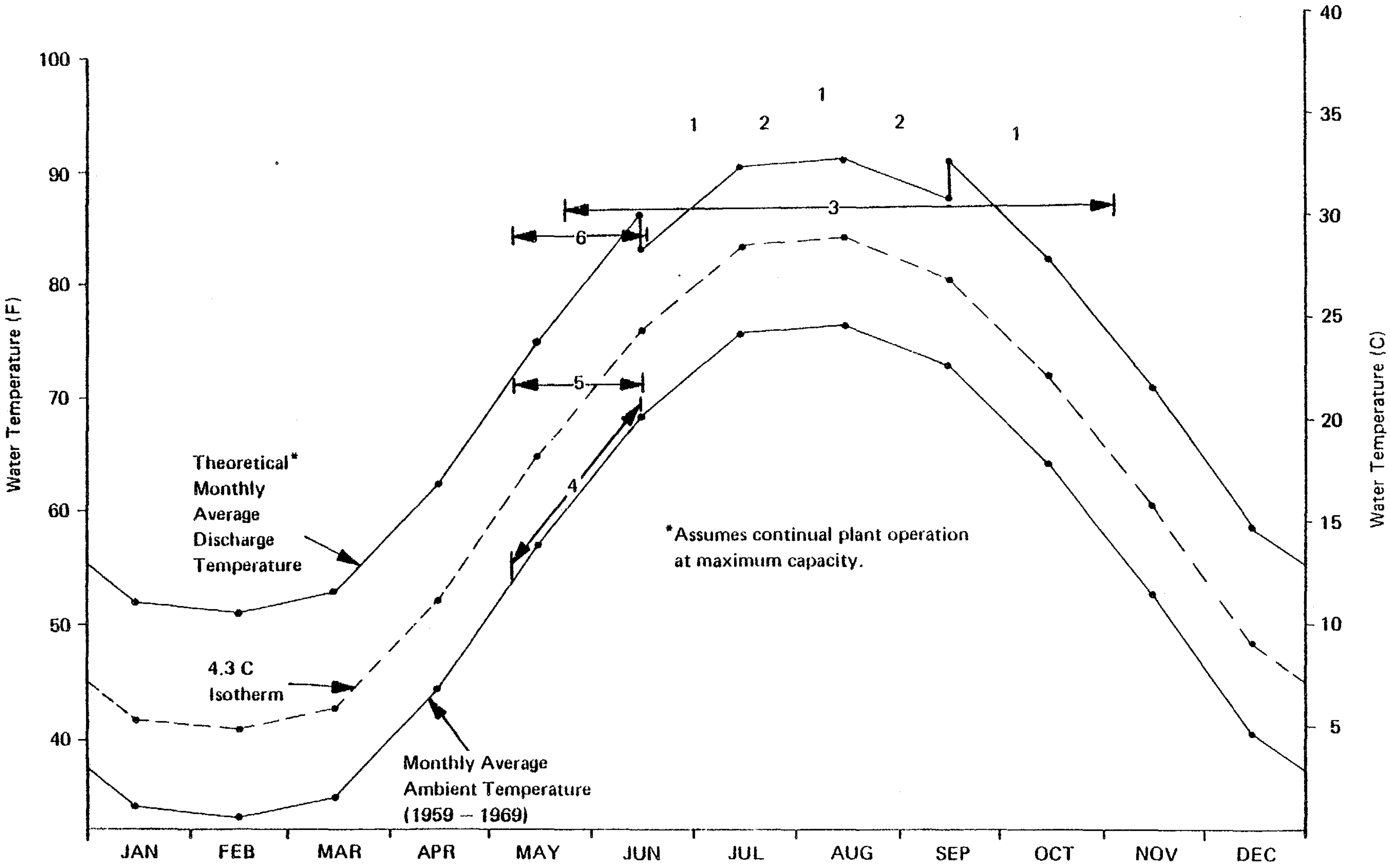


Figure 5.3-2. **Example of thermal effects parameters included in thermal effects diagrams for the Bowline Point plant.**

4.3 C (7.7 F) isotherm, the area and volume enclosed by the isotherm passing through the point are less than 0.7 acres and 3.0 acre-ft, respectively, and occur only in the immediate discharge vicinity where high velocities do not permit extended exposure. When a TL50 is plotted below the 4.3 C (7.7 F) isotherm, the area and volume enclosed by the isotherm passing through the point exceed the size of the high velocity exclusion zone. The thermal exclusion zone so defined represents a limitation on the potential habitat available to a species.

For some species, the ultimate upper incipient lethal temperature has been identified, and is used primarily for thermal effects evaluations during high summer temperatures. The ultimate upper incipient lethal temperature is defined as the temperature that is lethal to a species which has fully extended its ability to acclimate to higher temperatures. This thermal effects parameter, therefore, does not change with acclimation temperature, and is indicated on the thermal effects diagrams for each life stage as a horizontal line spanning the maximum ambient temperatures during summer months.

Other thermal effects parameters are plotted and interpreted in the same manner. These data points are plotted above the ambient temperature curve corresponding to the acclimation temperature at which the test was conducted. For example, the points marked number 2 on Figure 5.3-2 represent upper avoidance temperatures. Avoidance temperatures are usually somewhat less than upper lethal temperatures (points number 1). In the example shown in Figure 5.3-2, the avoidance temperatures exceed even the warmest plume isotherms, indicating that the RIS in question would not actively avoid any plume areas because of temperature alone.

The line marked number 3 represents the optimum temperature for growth and performance, as determined by final preferenda for RIS. Since final preferenda are independent of acclimation temperature, they are plotted on the thermal effects diagram over the time period when juveniles or adults are present at the plant. In this example case, the warmest plume isotherms exceed this optimum performance estimator. However, velocities at these warmer isotherms exceed 4 fps, as discussed in Subsection 5.3.3.2.3. Therefore, the lower isotherm areas of the plume would not interfere with the optimun level of growth and performance for this hypothetical species.

The line marked number 4 represents the spawning temperature range for the RIS. It serves to identify the temperatures at which spawning occurs, and thus the ambient river temperatures at which eggs and larvae would potentially be present in the vicinity of the plant. The time of the year that eggs and larvae typically occur in the vicinity of Bowline Point is indicated on the histograms beneath the thermal effects diagram, and generally correspond closely to the spawning temperatures indicated on the diagram.

The line marked number 5 represents the maximum temperature compatible with normal hatching success of eggs of the RIS. This parameter is plotted on the thermal effects diagram as a line spanning the range of ambient temperatures at which spawning occurs. In the example shown in Figure 5.3-2, this maximum occurs at isotherms less than 4.3 C (7.7 F) during the latter end of the spawning season. Thus, at that time suboptimal conditions for normal development will occur in a portion of the plume. The area or volume of the suboptimal zone is determined as described above from the isotherm-area or isotherm-volume relationships presented in Table 5.3-1.

The last line, numbered 6 on Figure 5.3-2, represents the short-exposure safe temperature for eggs of the RIS. This safe temperature is defined by the 30-minute TL95 (temperature at which 95 percent survival occurs). This line defines the maximum discharge temperature that eggs can tolerate for 30 minutes without reductions in normal hatching success upon return to ambient. Thirty-minute TL95s were also plotted on thermal effects diagrams for larvae and early juveniles. These values were usually plotted on the diagram according to acclimation temperature at which the test was performed. For some species, the number of values were too numerous to clearly display each point, and the range of TL95s were plotted over the period of time when that life stage is shown to be present in the vicinity of the Bowline Point plant. However, thermal effects evaluations were based on the actual values for each specific acclimation temperature.

The largest data base available on heat shock tolerance of early life stages was for 30-minute exposures, and for consistency these were used to illustrate heat shock tolerance on the thermal effects diagrams for most of the RIS. However, thermal tolerance is strongly dependent on the duration of exposure to elevated temperature (EA 1978b). Since the exposure to highest elevated temperatures during plume entrainment at Bowline Point is limited to only 5-10 seconds, the 30-minute data are highly conservative, and when available, data on shorter term exposures (primarily 5 and 10 minutes) were also used to assess the potential for heat shock of RIS by the Bowline Point plume. In the hypothetical egg shock example of Figure 5.3-2, the 30-minute TL95 line plotted exceeds maximum discharge temperatures except during a short period near the end of the spawning season. If available, TL95 data for shorter term exposures (as summarized in the thermal effects summary tables) would be consulted in this case to determine whether any effect may realistically be expected even late in the spawning season.

5.3.3.4 Seasonal Distribution Parameters

In order to place the predicted impacts in perspective, the seasonal distribution of each RIS life stage must be known. In other words, if a life stage is not in the plant vicinity when the potential for impact is predicted, then in reality no impact is possible. On the contrary, if a life stage is found in abundance in the plant vicinity during that same period, then impact resulting from interaction with the thermal plume is possible.

Below each thermal effects diagram, a series of seasonal distribution histograms have been plotted, corresponding to each RIS life stage. In this way the relative temporal abundance of each life stage can be determined, and the potential for impact subsequently placed in perspective.

5.3.3.5 Evaluations for Unusually Warm Years

Thermal effects evaluations were conducted on all RIS, as demonstrated in the preceding sections, for discharge temperatures predicted during normal ambient temperature regimes. In addition to assessing potential thermal effects on RIS during typical years, assessments were made to determine the effects of the Bowline Point plant's cooling water discharge for periods of time that were unseasonably warm. For this purpose, the areas and volumes of the plume exceeding maximum discharge temperatures were predicted for a hypothetical "unusually warm year," as described in Section 5.3.3.2.1. Because many of the temperature requirements were derived from thermal effects parameters that are dependent on acclimation (or spawning) temperature, evaluations for unusually warm periods other than summer varied little from those for the typical year.

Only those thermal effects parameters that were independent of acclimation and spawning temperatures (and in some cases, temperature limits derived from tests conducted at high acclimation temperatures [24.0-26.0 C]) were used for evaluating potential thermal effects during unusually warm summers. The evaluations for unusually warm summers indicated that the areas and volumes exceeding temperature requirements were only slightly larger than those determined for typical years, with no additional impact on the balanced indigenous community. Therefore, predictions of areas and volumes exceeding temperature requirements during unusually warm years are presented in summary tables along with predictions for typical years, but are not specifically discussed in the text of Subsection 5.3.4.

5.3.4 Thermal Effects Evaluations For Representative Important Species

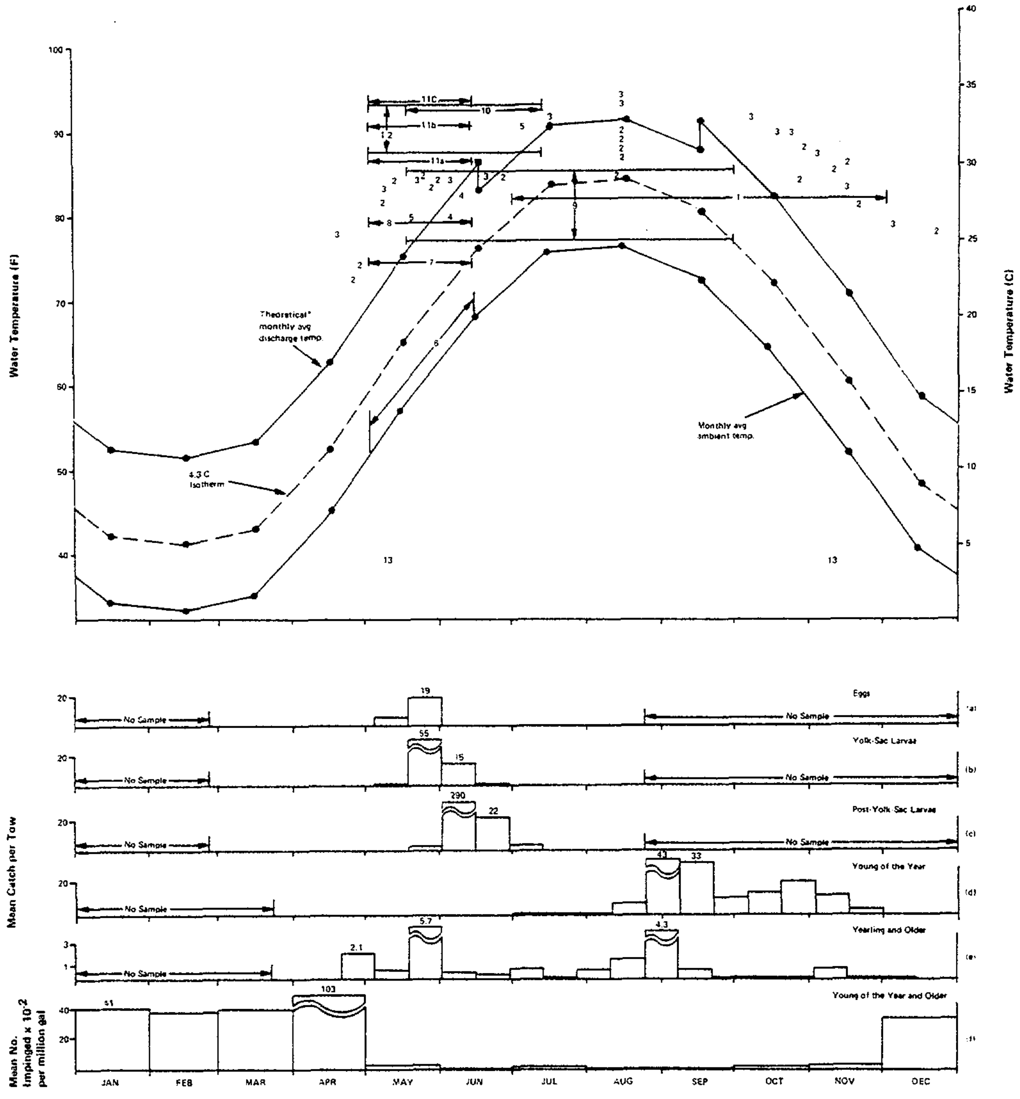
5.3.4.1 Striped Bass

The striped bass (Morone saxatilis) is an anadromous, coastal species that is distributed along the Atlantic coast of North America from the St. Lawrence River, Canada to the St. Johns River in northern Florida, and in the Gulf of Mexico from western Florida to Louisiana. Striped bass were introduced to the Pacific Coast in the Sacramento - San Joaquin River system of California in 1879 and 1883, and are now found from the Columbia River, Oregon, to southern California (Scott and Crossman 1973:p. 694). Along both east and west coasts of the United States, the striped bass is an important commercial and sport fish. It utilizes the Hudson River estuary primarily as a spawning and nursery area.

In the spring, mature striped bass migrate from coastal waters to spawn in freshwater areas of the Hudson River estuary where there are moderate to swift currents, narrow widths, and greater than average depths (McFadden 1977: pp. 5.7, 6.6). An important requirement for successful spawning appears to be a current sufficient to keep the semibuoyant eggs from settling to the bottom where they might become silted over and smother (Bigelow and Schroeder 1953:p. 394). Spawning occurs primarily between mile points (MP) 40 and 100 (TI 1976e:p. II-4) at water temperatures ranging from 11 to 20 C (TI 1976e:p. V-10; McFadden 1977:p. 7.25). Striped bass eggs are concentrated in the bottom strata of the water column (McFadden 1977:p. 6.6), and are found in the vicinity of Bowline Point during May (Figure 5.3-3). However, since the Bowline Point plant (MP 37.5) is located below the downstream edge of the principal striped bass spawning area, the abundance of striped bass eggs in the area of the plant is much lower than in areas farther upstream (TI 1976e:p. V-11; McFadden 1977:pp. 6.7, 6.15).

When present in the vicinity of Bowline Point, striped bass eggs may be exposed to elevated temperatures as a result of plume entrainment. Recent studies have demonstrated that striped bass eggs are quite tolerant of sudden temperature increases (EA 1978b:pp. 5.2-1 - 5.2-2). Tolerance limits for 30-minute exposures (TL95) range from 30.2 C for eggs in the gastrula stage to 34.1 C for eggs in the tail-free embryo stage (EA 1978b:Table 5.2-1) (Table 5.3-1). These tolerance limits exceed maximum discharge temperatures during the striped bass spawning season (Figure 5.3-3, lines 11a, 11b, and 11c); therefore, no mortality of plume entrained striped bass eggs is predicted.

Extended exposure to the lower temperature areas of the thermal plume should also not impair the survival of striped bass eggs. An incubation temperature of 23.7 C (continuous exposure throughout egg development) has been estimated as the upper limit of the optimum temperature range for normal hatch of



*Assumes continual plant operation at maximum capacity

Key to Thermal Effects Data Points

1. 27.8 C, final preferendum for juveniles (<170 mm); EA 1978b.
2. 22.5-33.0 C, upper avoidance temps, for juveniles; TI 1976d.
3. 25.5-34.8 C, upper incipient lethal temps. for juveniles (96-hr TL50); TI 1976d.
4. 26.4-27.9 C, 14-16-hr TL50 for yolk-sac larvae; EA 1978b.
5. 26.3-32.4 C, 24-hr TL50 for post-yolk-sac larvae; EA 1978b.
6. 11.0-20.0 C, normal spawning temp. range; TI 1976e, McFadden 1977.
7. 23.7 C, upper limit of optimum range for normal hatch; EA 1978b.
8. 26.3 C, TL50 for normal hatch, EA 1978b.
9. 25.1-29.6 C, optimum range for growth of post-yolk-sac larvae and early juveniles; EA 1978b.
10. 33.5 C, ultimate upper incipient lethal temp. for post-yolk-sac larvae (16-day TL50); EA 1978b.
11. 30.2-34.1 C, 30-min TL95s for eggs: (a) gastrula stage, (b) tail-bud embryo stage, (c) tail-free embryo stage; EA 1978b.
12. 30.8-34.0 C, range of 30-min TL95s for yolk-sac and post-yolk-sac larvae; EA 1978b.
13. 4.2 C, lower incipient lethal temp. for juveniles (96-hr TL50 + 2 C); EA 1978b.

Key to Seasonal Distribution Histograms

(a) Mean no. of eggs collected in 5-min plankton tows for 1974-1976. RM 37; TI 1975a, TI 1976a, TI 1977.
(b) Mean no. yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 37; TI 1975a, TI 1976a, TI 1977.
(c) Mean no. post-yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 37; TI 1975a, TI 1976a, TI 1977.
(d) Mean no. young of the year collected in beach seines for 1974-1975, RM 36-37; TI 1976b, TI 1976c.
(e) Mean no. yearling and older collected in beach seines for 1974-1975, RM 36-37; TI 1976b, TI 1976c.
(f) Mean no. young of the year and older from impingement collections for 1973-1976; Orange and Rockland 1977.

Figure 5.3-3. Thermal effects diagram for striped bass at the Bowline Point Generating Station on the Hudson River.

striped bass eggs (EA 1978b:p. 8.1-3, Table 8.2-1) (Table 5.3-2). Areas warmer than this optimum temperature during the striped bass spawning season occur only in the immediate vicinity of the discharge where high velocities do not permit extended exposure (Figure 5.3-3, line 7). Furthermore, striped bass eggs are not expected to remain in areas influenced by the thermal discharge from the Bowline Point plant throughout their entire incubation period because of (1) the predominately surface-oriented nature of the thermal plume and the tendency for the eggs to settle to the bottom water strata, and (2) the shifting orientation of the thermal plume because of tidal interactions.

Striped bass larvae are widely distributed throughout the Hudson River estuary from early May through July, occurring predominately in channel areas (McFadden 1977:pp. 6.6 - 6.10). Areas of greatest abundance are in the Croton-Haverstraw bays through Kingston regions (MP 34-93) (McFadden 1977: pp. 6.6 - 6.10), and include the Bowline Point area. Larvae and early juveniles begin to move from the main channel shoreward into nursery areas in shoals and along beaches during June and early July (McFadden 1977:pp. 5.9, 6.10; TI 1976e:p. V-17). During that period, involvement with the thermal discharge is greatest.

Young striped bass have a high tolerance of short-term thermal exposures during spring and early summer months when these life stages are present in the vicinity of Bowline Point. The 30-minute TL95s for striped bass yolk-sac larvae, post-yolk-sac larvae, and early juveniles range from 30.8 to 34.0 C (Table 5.3-2) (EA 1978b:Table 5.2-2), and exceed the maximum discharge temperatures during most of the larval plume entrainment season (Figure 5.3-3, line 12). At the end of that season, discharge temperatures will exceed the 30-minute TL95s. However, 5-minute TL95s (varying from 32.1-33.3 C) (Table 5.3-2)

TABLE 5.3-2 THERMAL EFFECTS SUMMARY TABLE FOR STRIPED BASS

Biological Activity To Be Protected	Thermal Effects Parameter	Temp. Limit or Range (C)	Reference	Maximum Area of Thermal Plume[a] Exceeding Temperature Limit During Typical Years: Surface Area: Acres	Maximum Area of Thermal Plume[a] Exceeding Temperature Limit During Typical Years: Surface Area: Percent[b] Near-field	Maximum Area of Thermal Plume[a] Exceeding Temperature Limit During Typical Years: Volume: Acre-ft	Maximum Area of Thermal Plume[a] Exceeding Temperature Limit During Typical Years: Volume: Percent[b] Near-Field	Maximum Area of Thermal Plume[a] Exceeding Temperature Limit During Unusually Warm Years: Surface Area: Acres	Maximum Area of Thermal Plume[a] Exceeding Temperature Limit During Unusually Warm Years: Surface Area: Percent[b] Near-field	Maximum Area of Thermal Plume[a] Exceeding Temperature Limit During Unusually Warm Years: Volume: Acre-ft	Maximum Area of Thermal Plume[a] Exceeding Temperature Limit During Unusually Warm Years: Volume: Percent[b] Near-field
Maximum for Survival											
Juveniles	96-hr TL50	25.5-34.8	TI 1976d	0	0	0	0	<0.7	<0.01	<2.99	<0.002
Minimum Avoidance											
Juveniles	Upper avoidance temp.	22.5-33.0	TI 1976d	<0.7	<0.01	<2.99	<0.002	<0.7	<0.01	<2.99	<0.002
Maximum Temperature for Early Development											
Eggs	Upper limit of optimum range for hatch	23.7	EA 1978b	<0.6	<0.007	<1.4	<0.001	(c)	(c)	(c)	(c)
Eggs	TL50	26.3	EA 1978b	<0.6	<0.007	<1.4	<0.001	(c)	(c)	(c)	(c)
Yolk-sac larvae	24-hr TL50	26.4-27.9	EA 1978b	<0.6	<0.007	<1.4	<0.001	(c)	(c)	(c)	(c)
Post-yolk-sac larvae	24-hr TL50	26.3-32.4	EA 1978b	0	0	0	0	<0.7	<0.010	<2.99	<0.002
Post-yolk-sac larvae	Ult. upper inc. lethal temp.	33.5	EA 1978b	0	0	0	0	<0.7	<0.010	<2.99	<0.002
Optimum for Performance and Growth											
Larvae and early juveniles	Upper limit of opt. growth range	29.6	EA 1978b	<0.7	<0.01	<2.99	<0.002	3.7	0.052	32.1	0.022
Juveniles	Final preferendum	27.8	EA 1978b	<7.4	<0.104	<26.4	<0.018	>141.0	>1.995	>604.0	>0.410
Thermal Shock Tolerance											
Cold Shock											
Juveniles	96-hr TL50 + 2.0 C	4.2	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA

(a) Calculations were based on the isotherm exceeding the temperature limit during operation at maximum capacity; areas and volumes are predicted according to actual field surveys conducted when the plant operation load was 93.3-93.8 percent of capacity.

(b) Percent available volume or area based on a near-field area calculated as two tidal excursions (ebb) and flood), one upstream (1.9 miles), and one downstream (3.6 miles); surface area of this near-field area = 7,067 acres, and volume = 146,987 acre-ft.

(c) The maximum area of the thermal plume exceeding temperature requirements for early life stages does not change during unusually warm years, since the occurrence of these life stages is dependent upon spawning temperatures and thus on the timing of spawning.

Note: NA = not applicable.

TABLE 5.3-2 (CONT.)

Biological Activity To Be Protected	Thermal Effects Parameter	Temp. Limit or Range (C)	Reference	Maximum Area of Thermal Plume(a) Exceeding Temperature Limit During Typical Years				Maximum Area of Thermal Plume(a) Exceeding Temperature Limit During Unusually Warm Years			
				Surface Area		Volume		Surface Area		Volume	
				Acres	Percent(b) Near-field	Acre-ft	Percent(b) Near-Field	Acres	Percent(b) Near-field	Acre-ft	Percent(b) Near-field
Plume Entrainment Shock											
Eggs											
Blastula stage	5-minute TL95(c)	30.2	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Gastrula stage	5-minute TL95(c)	34.4	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Gastrula stage	30-minute TL95	30.2	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Tailbud embryo	30-minute TL95	32.5	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Tailfree embryo	30-minute TL95	34.1	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Yolk-sac larvae	5-minute TL95(c)	33.8-37.0	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
(1 day old)	30-minute TL95	31.1-34.0	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Post-yolk-sac											
larvae (6-35	5-minute TL95(c)	32.1-33.3	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
days old)	30-minute TL95	30.8-34.0	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Early juvenile	5-minute TL95(c)	34.8	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA

(a) Calculations were based on the isotherm exceeding the temperature limit during operation at maximum capacity; areas and volumes are predicted according to actual field surveys conducted when the plant operation load was 93.3-93.8 percent of capacity.

(b) Percent available volume or area based on a near-field area calculated as two tidal excursions (ebb) and flood), one upstream (1.9 miles), and one downstream (3.6 miles); surface area of this near-field area = 7,067 acres, and volume = 146,987 acre-ft.

(c) Data not plotted on Figure 5.3-3.

Note: NA = not applicable.

exceed these theoretical maximum discharge temperatures during this time. Since actual entrainment exposure durations to peak discharge temperatures are no more than a few seconds (Subsection 3.3.1.5), no mortality of striped bass larvae or early juveniles is predicted as a result of plume entrainment.

Whereas exposures to the higher plume temperatures are limited to only 5-10 seconds, striped bass larvae may be exposed to the lower plume isotherms (less than 4.3 C above ambient) for longer time periods (Subsection 3.3.1.5). The 14- and 16-hour TL50s for yolk-sac larvae range from 26.4 to 27.9 C, and 24-hour TL50s for post-yolk-sac larvae range from 26.3 to 32.4 C, depending on acclimation (ambient) temperatures (EA 1978b:Table 6.2-1) (Figure 5.3-3, data points number 4 and 5). Areas of the plume warmer than these tolerance limits occur only in the immediate vicinity of the discharge where velocities do not permit extended exposure (Table 5.3-2). The ultimate upper incipient lethal temperature (16-day TL50) for striped bass post-yolk-sac larvae was determined to be 33.5 C (Table 5.3-2) (EA 1978b:p. 9.2-1). This exceeds maximum discharge temperatures during periods of larval abundance (Figure 5.3-3, line 10). Therefore, extended exposures to the lower elevated temperatures of the thermal plume should have no detrimental effect on the survival of striped bass larvae.

The upper limit of the optimum temperature range for growth and development of striped bass post-yolk-sac larvae and early juveniles is 29.6 C (EA 1978b: p. 9.2-1) (Figure 5.3-3, line number 9). This exceeds plume temperatures in all areas except the immediate vicinity of the discharge, where high discharge velocities do not permit extended residence (Table 5.3-2). Optimum temperatures for growth (25.1-29.6 C) generally exceed ambient river temperatures.

Young-of-the-year and yearling striped bass are abundant in the Bowline Point vicinity during summer and fall months (Figure 5.3-3) when downstream and shoreward migrations occur within the estuary (McFadden 1977:p. 6.10). Most of the juvenile striped bass population is distributed within the shore zones of the estuary during these months (McFadden 1977:p. 6.10). Therefore, juvenile striped bass would be exposed to the lower isotherms of the thermal plume on an intermittent basis, depending on the tidal currents and the wind direction.

Striped bass juveniles, like earlier life stages, appear to be very tolerant of high temperatures. The upper limit of the temperature range permitting survival of striped bass juveniles ranges from 25.5 to 34.8 C (96-hour TL50s), depending on acclimation (ambient) temperatures (TI 1976d:pp. V-35 - V-36). These tolerance limits exceed the maximum discharge temperatures of the Bowline Point plant during all times of the year (Figure 5.3-3, data points number 3). Furthermore, avoidance temperatures reported for striped bass juveniles (TI 1976d:p. V-28, V-30) occur only in the immediate vicinity of the discharge where high velocities do not permit extended residence (Figure 5.3-3, data points number 2). Maximum areas of the thermal plume exceeding tolerance limits and avoidance temperatures determined at high acclimation temperatures (26.0-27.5 C) are less than 0.7 acres (Table 5.3-2). Therefore, striped bass juveniles would not be excluded from any major habitats in the vicinity of Bowline Point as a result of the elevated temperatures.

The optimum temperature for growth and performance of juvenile striped bass, as estimated by the final preferendum, is 27.8 C (EA 1978b:p. 10.2-5) (Figure 5.3-3, line number 1). Maximum areas and volumes of the discharge that exceed the final preferendum are less than 7.4 acres and 26.4 acre-ft, respectively

(Table 5.3-2). However, the final preferendum only estimates some point within the optimum temperature range, and satisfactory growth and performance may occur at even higher temperatures. The observed range of preferred temperatures reported for striped bass juveniles by EA (1978b:Table 10.2-1) typically extended to approximately 30 C. Areas and volumes of the thermal plume exceeding this temperature encompass less than 0.7 acres and 2.99 acre-ft, respectively (Table 5.3-2).

During the late fall, young-of-the-year and yearling striped bass densities in the Bowline Point vicinity decline to low winter levels (Figure 5.3-3) as the fish move into deeper waters (Subsection 4.6.3.3.1). Densities in the thermal plume decline as well (ORU 1977:p. 10.1-52). Thus, the potential for cold shock of warm-acclimated fish following a total plant shutdown is minimized. Periodically during the winter months, however, striped bass migrate into the Bowline Point vicinity, and their movements have been highly correlated with periods of salinity intrusion (McFadden 1977:p. 13.26). These periods are often followed by periods of peak impingement at the intake screens (McFadden 1977:p. 13.27) (Figure 5.3-3). Nonetheless, striped bass have demonstrated a tolerance of large instantaneous drops in temperature, and therefore should be able to survive most cold shocks. For example, the lower safe temperature (96-hour TL50 + 2 C) for striped bass acclimated to 17.0 C is 4.2 C (EA 1978b: p. 7.2-1) (Figure 5.3-3, data points number 13). Texas Instruments (1976d: pp. V-40 - V-41) determined that striped bass juveniles acclimated to 10 C could tolerate a temperature decrease of at least 8 C to a low temperature of 2 C. Furthermore, the potential for cold shock of striped bass is minimized by (1) the low densities of fish in the plume during winter months, and (2) the fact that high discharge velocities prevent fish from becoming acclimated to temperatures greater than 4.3 C above ambient. While no data is available for cold shocks to temperatures below 2.0 C, it is unlikely that a drop in temperature from 4.3 C to 0.0 C would result in mortality.

Striped bass adults are generally found in the lower estuary and nearshore coastal areas except during the spawning period (McFadden 1977:p. 7.158); consequently the potential contact of striped bass adults with the thermal plume of the Bowline Point plant is restricted predominately to spring months during spawning migrations to upstream areas. Since the Bowline Point plant's thermal plume does not extend into the main channel area, and is largely a surface phenomenon in the shoal areas, the thermal plume is not expected to block striped bass migrations. This is supported by the fact that the major spawning grounds of striped bass in the Hudson River estuary (based on the distribution of striped bass eggs during recent years) are located above the Bowline Point plant. In order to reach these spawning grounds, adults would necessarily have to move past the plant during their upstream spawning runs.

In summary:

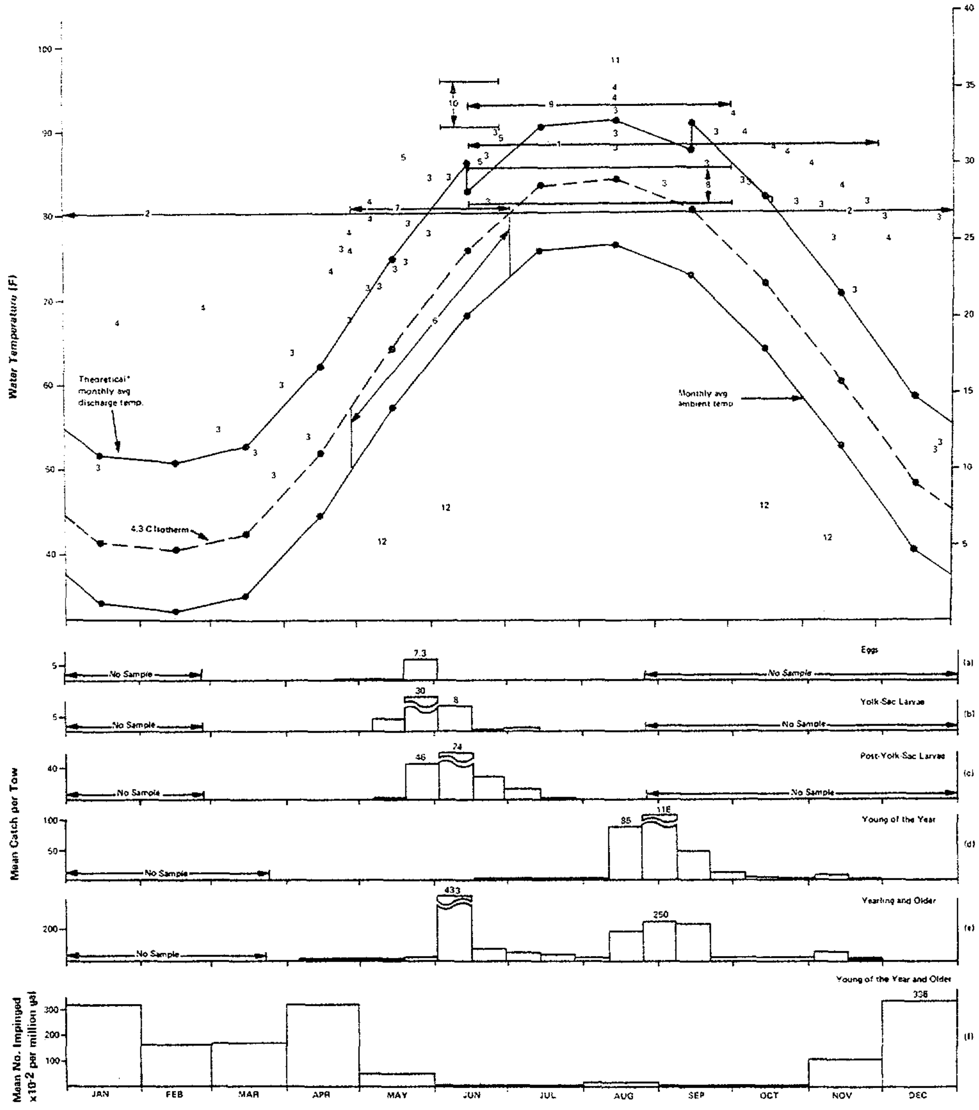
1. Striped bass occur in the vicinity of Bowline Point throughout most of the year, and are susceptible to thermal plume exposures depending on the occurrence and distribution of each life stage within the estuary.
2. Eggs and larvae are very tolerant of short exposures to elevated temperatures, and little or no mortality is predicted to occur as a result of plume entrainment.
3. Plume temperatures exceed the extended-exposure thermal tolerance limits of all life stages only in the immediate vicinity of the discharge (less than 0.7 acres and 2.99 acre-ft), where exposures are limited to 5-10 seconds because of the high discharge velocities.

4. Temperatures that would be expected to produce an avoidance response also occur only in the immediate vicinity of the discharge.
5. Thus, striped bass would not be excluded from any major habitat within the vicinity of Bowline Point that may be influenced by the lower isotherms of the thermal plume (up to 4.3 C above ambient).
6. The potential for mortality of striped bass as a result of cold shock in the event of a plant shutdown is minimal.
7. The thermal plume created by the Bowline Point plant does not create an impassable barrier for migrating adult striped bass.

5.3.4.2 White Perch

The white perch (*Morone americana*) is a semianadromous, euryhaline fish usually restricted to brackish and freshwater (Mansueti 1964:p. 4), and is common in the Hudson River below Albany (MP 125) (Scott and Crossman 1973:p. 685). It is regarded as a good food fish and is mainly sought by sport fishermen in the Hudson River estuary during periods when larger game fish, such as striped bass and American shad, are not available (TI 1976e:p. V-33).

In the Hudson River estuary, white perch spawn during spring and early summer following upstream migrations to areas of fresh or slightly brackish waters primarily north of Croton Bay (MP 38) (McFadden 1977:p. 5.15). The eggs are demersal, adhesive, and are deposited in shallow waters near shore or in tributary streams (Mansueti 1964:p. 9). White perch eggs are found in the vicinity of Bowline Point largely during May (Figure 5.3-4). The susceptibility of white perch eggs to thermal plume exposures is generally low, since eggs sink to the bottom and become attached to the substrate, and are predominately found in areas upstream of Bowline Point.



*Assumes continual plant operation at maximum capacity.

Key to Thermal Effects Data Points

1. 31.2 C, final preferendum for young of the year (<60 mm); EA 1978b.
2. 26.8 C, final preferendum for adults (>150 mm); EA 1978b.
3. 9.5-34.5 C, upper avoidance temp. for adults and juveniles; TI 1976d.
4. 19.5-35.0 C, upper incipient lethal temp. for adults and juveniles (96-hr TL50); TI 1976d.
5. 30.2-31.8 C, 24-hr TL50 for yolk-sac larvae; EA 1978b.
6. 10-22.6 C, spawning temp.; TI 1976e.
7. 27 C, minimum estimate of upper limit of optimum range for normal hatch; EA 1978b.
8. 27.3-29-7 C, optimum range for growth of early juveniles; EA 1978b.
9. 33.8 C, ultimate upper incipient lethal temp. for early juveniles (14-day TL50); EA 1978b.
10. 32.4-35.4 C, range of 30-min TL95s for yolk-sac larvae (1-day-old) at acclimation temps. from 18 to 22 C; EA 1978b.
11. *36.7 C, 30-min TL95 for early juveniles; EA 1978b.*
12. 5.3-7.5 C, lower incipient lethal temp. for adults and juveniles (96-hr TL50 + 2 C); EA 1978b.

Key to Seasonal Distribution Histograms

(a) Mean no. eggs collected in 5-min plankton tows for 1974-1976, RM 37; TI 1975a, TI 1976a, TI 1977.
(b) Mean no. yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 37; TI 1975a, TI 1976a, TI 1977.
(c) Mean no. post-yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 37; TI 1975a, TI 1976a, TI 1977.
(d) Mean no. young of the year collected in beach seines for 1974-1975, RM 36-37; TI 1976b, TI 1976c.
(e) Mean no. yearling and older collected in beach seines for 1974-1975, RM 36-37; TI 1976b, TI 1976c.
(f) Mean no. young of the year and older from impingement collections *for 1973-1976; Orange and Rockland 1977.*

Figure 5.3-4. Thermal effects diagram for white perch at the Bowline Point Generating Station on the Hudson River.

White perch eggs appear to be quite tolerant of temperature increases. Schubel (1974:pp. 112-113) reported that white perch eggs could withstand temperature shocks of at least 10 C during tests simulating plume and plant entrainment. Therefore, those white perch eggs which are entrained into the Bowline Point plant's thermal plume should not be affected by thermal shock, since plant delta-Ts are generally less than 10 C (Subsection 3.2.4).

White perch eggs are also relatively tolerant of extended exposures to high temperatures. An incubation temperature of 27.0 C has been estimated as the upper limit of the optimum temperature range for normal hatch of white perch eggs (EA 1978b:Table 8.2-8). During the white perch spawning season, thermal plume areas with temperatures greater than this optimum temperature for normal hatch occur only in the immediate vicinity of the discharge (<0.7 acres and 2.99 acre-ft) where high velocities do not permit extended exposure (Figure 5.3-4, line number 7) (Table 5.3-3). Therefore, the survival and normal hatch of white perch eggs should not be impaired as a result of exposure to the lower isotherm areas of the thermal plume (areas less than 4.3 C above ambient).

White perch larvae move downstream after hatch toward brackish water (Dovel 1971:p. 5), and occur predominately in channel areas (McFadden 1977:p. 6.31). Although they are relatively abundant in the vicinity of Bowline Point during May and June (Figure 5.3-4), young white perch remain concentrated in the deeper (>20 ft) areas of the estuary until late June or early July when juveniles begin to move into the shore zones (McFadden 1977:p. 6.31). Since thermal effluents from the Bowline Point plant tend to float on or near the surface, the susceptibility of white perch larvae to thermal plume exposures is substantially reduced.

TABLE 5.3-3 THERMAL EFFECTS SUMMARY TABLE FOR WHITE PERCH

Biological Activity To Be Protected	Thermal Effects Parameter	Temp. Limit or Range (C)	Reference	Maximum Area of Thermal Plume(a) Exceeding Temperature Limit During Typical Years				Maximum Area of Thermal Plume(a) Exceeding Temperature Limit During Unusually Warm Years			
				Surface Area		Volume		Surface Area		Volume	
				Acres	Percent(b) Near-field	Acre-ft	Percent(b) Near-Field	Acres	Percent(b) Near-field	Acre-ft	Percent(b) Near-field
Maximum for Survival											
Juveniles and adults	96-hr TL50	19.5-35.0	TI 1976d	0	0	0	0	<0.7	<0.01	<2.99	<0.002
Minimum Avoidance											
Juveniles and adults	Upper avoidance temp.	9.5-34.5	TI 1976d	<0.7	<0.01	<2.99	<0.002	<0.7	<0.01	<2.99	<0.002
Maximum Temperature for Early Development											
Eggs	Estimate of upper limit of optimum range for hatch	27.0	EA 1978b	<0.7	<0.01	<2.99	<0.002	(c)	(c)	(c)	(c)
Yolk-sac larvae	24-hr TL50	30.2-31.8	EA 1978b	0	0	0	0	(c)	(c)	(c)	(c)
Early juveniles	Ult. upper inc. lethal temp.	33.8	EA 1978b	0	0	0	0	<0.7	<0.01	<2.99	<0.002
Optimum for Performance and Growth											
Early juveniles	Upper limit of opt. growth range	29.7	EA 1978b	<0.7	<0.01	<2.99	<0.002	3.7	0.052	32.1	0.022
Young of the year	Final preferendum	31.2	EA 1978b	<0.7	<0.01	<2.99	<0.002	<0.7	<0.01	<2.99	<0.002
Adults	Final preferendum	26.8	EA 1978b	10.1	0.143	113.0	0.077	>29.4	>0.415	>321.0	>0.281
Thermal Shock Tolerance											
Cold shock											
Juveniles and adults	96-hr TL50 + 2.0C	5.3-7.5	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Plume Entrainment Shock											
Yolk-sac larvae (1 day old)	10-min TL95(d)	34.2-38.2	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
	30-min TL95	32.4-35.4	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Early juveniles	10-min TL95(d)	35.9	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
	30-min TL95	36.7	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA

(a) Calculations were based on the isotherm exceeding the temperature limit during operation at maximum capacity; areas and volumes are predicted according to actual field surveys conducted when the plant operation load was 93.3-93.8 percent of capacity.

(b) Percent available volume or area based on a near-field area calculated as two tidal excursions (ebb) and flood), one upstream (1.9 miles), and one downstream (3.6 miles); surface area of this near-field area = 7,067 acres, and volume = 146,987 acre-ft.

(c) The maximum area of the thermal plume exceeding temperature requirements for early life stages does not change during unusually warm years, since the occurrence of these life stages is dependent upon spawning temperatures and thus on the timing of spawning.

(d) Data not plotted on Figure 5.3-4.

Note: NA = not applicable.

Young white perch are very tolerant of short-term thermal exposures. The 30-minute TL95s for yolk-sac larvae and early juveniles range from 32.4 C to 36.7 C, depending on acclimation (ambient) temperatures (Table 5.3-3) (EA 1978b:Table 5.2-3). These thermal tolerance limits exceed maximum discharge temperatures during spring and early summer by several degrees centigrade (Figure 5.3-4, line number 10 and data point 11). Thus, mortality of young white perch is not predicted to occur because of plume entrainment.

Young white perch are also quite tolerant of extended exposures to high temperatures. The 24-hour TL50s for yolk-sac larvae acclimated to temperatures representative of river ambients during the period of peak abundance range from 30.2 C to 31.8 C (EA 1978b:Table 6.2-2). These tolerance limits exceed the maximum discharge temperatures during the white perch spawning season (Figure 5.3-4, data points number 5). The ultimate upper incipient lethal temperature for early juveniles, 33.8 C (EA 1978b:p. 9.2-8), also exceeds the maximum discharge temperatures (Figure 5.3-4, line number 9). Therefore, the lower isotherm areas of the thermal plume should not be excluded as suitable habitat for young white perch based on temperature requirements for survival.

Early juvenile white perch moving into shore zone regions during midsummer may utilize areas within the influence of the thermal discharge from the Bowline Point plant as a nursery area. The optimum temperature range for growth of early juvenile white perch is 27.3-29.7 C (EA 1978b:p. 9.2-8). The upper limit of this optimum range, 29.7 C, exceeds the maximum habitable isotherm (4.3 C above ambient) at all times (Figure 5.3-4, line number 8).

Juvenile and adult white perch are abundant in the shoal and shore zone areas in the Bowline Point vicinity during August and September (Figure 5.3-4). At that time they could be potentially exposed to the elevated plume temperatures. The 96-hour TL50s for white perch juveniles and adults range from 19.5 to 35.0 C, depending on acclimation (ambient) temperatures (TI 1976d: pp. V-35 - V-36). These tolerance limits exceed the maximum discharge temperatures during all times of the year, according to their respective acclimation temperatures (Figure 5.3-4, data points number 4). The maximum areas and volumes of the discharge that would be potentially avoided because of high temperatures, based on avoidance temperatures reported by TI (1976d:pp. V-27 - V-29), are less than 0.7 acres and 2.99 acre-ft (Table 5.3-3), and occur only in areas of the thermal plume where discharge velocities do not permit residence (Figure 5.3-4, data points number 3). Therefore, white perch juveniles andadults that encounter the area influenced by the thermal discharge from the Bowline Point plant should not be excluded from any major habitat because of the elevated temperatures.

The optimum temperatures for growth and performance of young-of-the-year and adult white perch, as approximated by final preferenda, are 31.2 C and 26.8 C, respectively (EA 1978b:p. 10.2-7) (Figure 5.3-4, lines number 1 and 2). Maximum areas of the thermal plume that exceed the final preferendum of young-of-the-year and adult white perch are 0.7 and 10.1 acres, respectively; maximum volumes are 2.99 and 113 acre-ft, respectively (Table 5.3-3). Since final preferenda only estimate some point within the optimum temperature range, satisfactory growth and performance may occur at even higher temperatures.

During the late fall, white perch densities in the Bowline Point vicinity decline to low winter levels (Figure 5.3-4) as the fish move into deeper waters (Subsection 4.6.3.3.2). Densities in the thermal plume decline as well (ORU 1977:p. 10.1-52). Thus, the potential for cold shock of warm-acclimated fish following a total plant outage is minimized. Periodically during the winter months, however, white perch migrate into the Bowline Point vicinity, and their movements have been highly correlated with periods of salinity intrusion (McFadden 1977:p. 13.26). These periods are often followed by periods of peak impingement at the intake screens (McFadden 1977:p. 13.27) (Figure 5.3-4). Nonetheless, white perch have demonstrated a tolerance of large instantaneous drops in temperature, and therefore should be able to survive most cold shocks. For example, the lower safe temperatures (96-hour TL50 + 2 C) for white perch juveniles acclimated to 22.5 C and adults and juveniles acclimated to 17.0 C are 7.5 C and 5.3 C, respectively (EA 1978b:Table 7.2-1) (Figure 5.3-4, data points number 12). TI (1976d:pp. V-40 - V-41) determined that white perch acclimated to 15 C could tolerate a temperature decrease of 13 C to a low temperature of 2 C. The potential for cold shock of white perch is further minimized by (1) the low densities of fish in the plume during winter months, and (2) by the fact that high discharge velocities prevent fish from becoming acclimated to temperatures greater than 4.3 C above ambient. Although no data are available for cold shocks to temperatures below 2.0 C, it is unlikely that a drop in temperature from 4.3 C to 0.0 C would result in mortality.

In summary:

1. White perch occur in the vicinity of Bowline Point throughout the year, and therefore are susceptible to thermal plume exposures.
2. The probability of exposure of eggs and larvae to the thermal plume is decreased considerably because of their concentration in upstream and channel areas of the estuary.
3. Early life stages of white perch are extremely tolerant of both short-term and extended exposures to high temperatures, and mortality

is not predicted because of entrainment into even the warmest portions of the thermal plume.

4. Juveniles and adults are often abundant in the vicinity of Bowline Point, but are not expected to be excluded from any major habitat because of the warm temperatures.
5. The potential for mortality of white perch as a result of cold shock in the event of a plant shutdown is minimal.

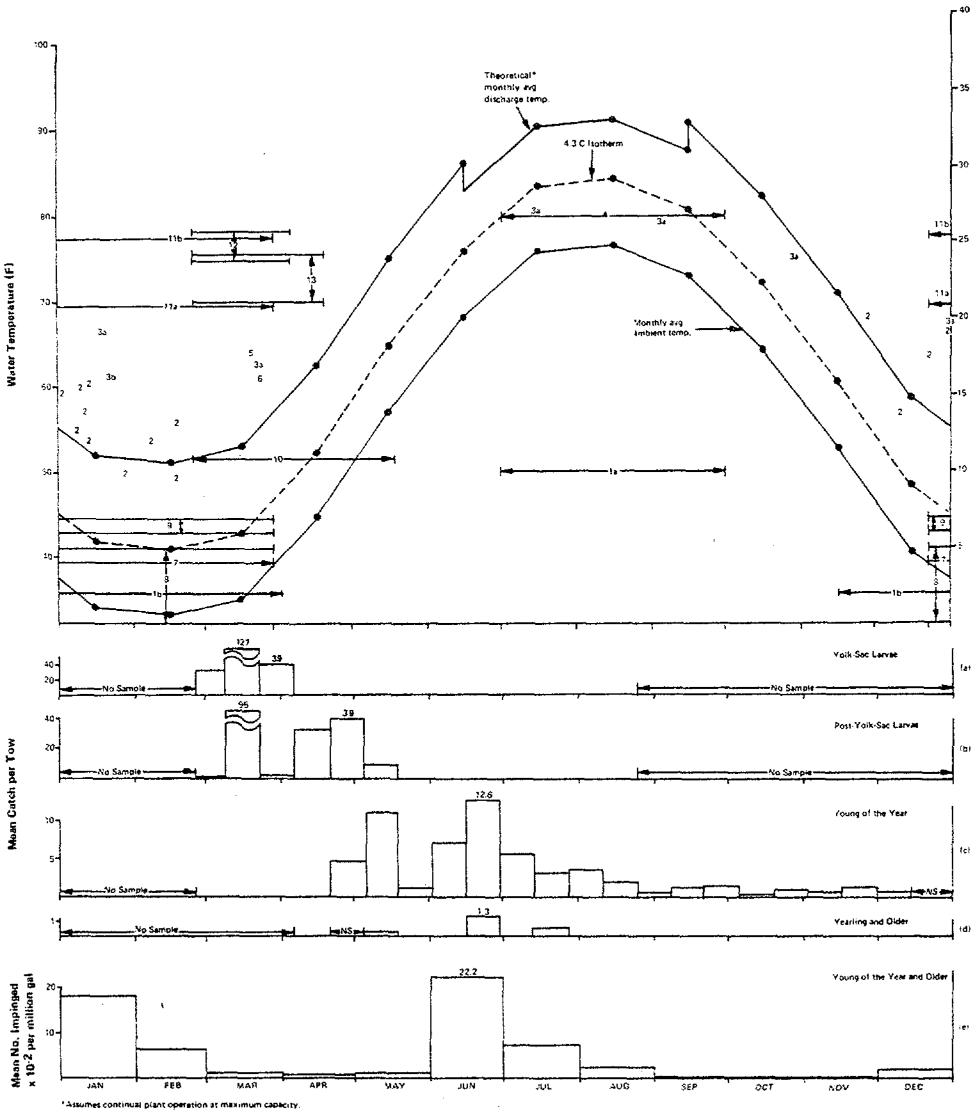
5.3.4.3 Atlantic Tomcod

The Atlantic tomcod (*Microgadus tomcod*) is an inshore marine and estuarine species distributed principally along the Atlantic coast of North America from southern Labrador to the Hudson River estuary, and occurs incidentally as far south as Virginia. Although small, tomcod are frequently the object of a recreational or small commercial fishery in areas where they are sufficiently abundant (TI 1976e:p. V-130). The tomcod population in the Hudson River is largely composed of a single year class (McFadden 1977:pp. 14.7, 14.9).

Atlantic tomcod are predominately anadromous, migrating from lower estuaries and coastal waters during late fall and winter into brackish and freshwaters of rivers and estuaries to spawn (Howe 1971:pp. 1, 34-36, 54). During winter fishery surveys on the Hudson River in 1973, the largest catches of spawning adults occurred during late December and January at water temperatures of approximately 1 C and maximum salinity of 1 ppt between Haverstraw Bay and the Newburgh-Beacon Bridge (MP 40-70) (TI 1976e:pp. V-130 - V-131, II-5). Although information on tomcod egg distribution in the Hudson River estuary is lacking, it is likely that the eggs remain within the spawning area throughout their 30-40 day incubation period owing to their adhesive and demersal properties. Since the principal spawning area for Atlantic tomcod is in areas of the estuary upstream of Bowline Point (MP 37.5), the number of eggs occurring near the area of the plant is low.

Atlantic tomcod eggs are very tolerant of high temperatures when exposed for short periods of time. Thirty-minute TL95s for tomcod eggs 15-30 days old range from 20.8 to 25.3 C (EA 1978b:Table 5.2-4). These safe temperatures exceed the maximum discharge temperatures during the spawning season by several degrees centigrade (Figure 5.3-5, lines 11a and 11b). Consequently, no mortality of Atlantic tomcod eggs would occur because of potential thermal exposures resulting from plume entrainment. Although exposure to the higher plume temperatures would be limited to only 5-10 seconds, Atlantic tomcod eggs that may occur on the bottom near the discharge would be intermittently exposed to the lower isotherms of the thermal plume for longer periods, depending on the tide. An incubation temperature of 4.9 C has been determined as the upper limit of the optimum range for normal hatch of Atlantic tomcod eggs (EA 1978b:p. 8.1-8) (Figure 5.3-5, line number 8). During the period of peak spawning activity (January), the area of the thermal plume exceeding this temperature is less than 0.6 acres and the volume less than 1.4 acre-ft (Table 5.3-4. At the extremes of the spawning season, virtually the entire plume exceeds 4.9 C (Table 5.3-3). However, since few eggs are expected in the Bowline Point vicinity, this area of exclusion is of little importance. Also, since thermal exposures are intermittent rather than continuous in the lower isotherm areas because of tidal variations, the maximum temperatures tolerated under these conditions by tomcod eggs probably exceed the 4.9 C cited above.

After hatch, Atlantic tomcod larvae drift downstream into the lower estuary and downstream regions of the middle estuary, where they occur predominately in the channel areas (McFadden 1977:p. 6.42). Tomcod larvae are most abundant



*Assumes continual plant operation at maximum capacity.

Key to Thermal Effects Data Points

1. *<2-10 C, final preferendum: (a) juveniles during the summer,* (b) adults during the winter; EA 1978b.
2. 9.6-20.0 C, upper avoidance temp. for adults; TI 1976d.
3. 16.3-26.8 C, 96-hr TL50, upper incipient lethal temps. for adults and juveniles; (a) EA 1978b, (b) TI 1976d.
4. 26.6 C, ultimate upper incipient lethal temp. for juveniles during the summer; EA 1978b.
5. *17.8 C, 24-hr TL50 for yolk-sac larvae (1 day old); EA 1978b.*
6. 16.1 C, 24-hr TL50 for post-yolk-sac larvae; EA 1978b.
7. 0.0-4.0 C, normal spawning temp.; Scott and Crossman 1973.
8. 0.0-4.9 C, optimum range for normal hatch; EA 1978b.
9. 6.0-6.9 C, range of TL50s for normal hatch; EA 1978b.
10. 10.9 C, minimum estimate of optimum temp. for growth and development from hatch to advanced post-yolk-sac larvae; EA 1978b.
11. 20.8-25.3 C, *30-min TL95s for eggs: (a) tailbud embryo stage,* (b) eyed-up embryo stage; EA 1978b.
12. 23.8-25.7 C, range of 30-min TL95s for yolk-sac larvae (1-day-old); EA1978b.
13. 21.1-24.2 C, range of 30-min TL95s at acclimation temps. of 3.0-7.5C for post-yolk-sac larvae; EA 1978b.

Key to Seasonal Distribution Histograms

(a) *Mean no. yolk-sac larvae collected in 5-min plankton tows for 1974-1976,* RM 37; TI 1975a, TI 1976a, TI 1977.
(b) Mean no. post-yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 37; TI 1975a, TI 1976a, TI 1977.
(c) Mean no. young of the year collected in 5-min plankton tows for 1974-1976, RM 36-37; TI 1975a, TI 1976a, TI 1977.
(d) Mean no. yearling and older collected in 5-min bottom trawls for 1974-1975, RM 36-37; TI 1976b, TI 1976c.
(e) Mean no. young of the year and older from impingement collections for 1973-1976; Orange and Rockland 1977.

Figure 5.3-5. Thermal effects diagram for Atlantic tomcod at the Bowline Point Generating Station on the Hudson River.

TABLE 5.3-4 THERMAL EFFECTS SUMMARY TABLE FOR ATLANTIC TOMCOD

Biological Activity To Be Protected	Thermal Effects Parameter	Temp. Limit or Range (C)	Reference	Maximum Area of Thermal Plume[(a)] Exceeding Temperature Limit During Typical Years: Surface Area, Acres	Surface Area, Percent[(b)] Near-field	Volume, Acre-ft	Volume, Percent[(b)] Near-Field	Maximum Area of Thermal Plume[(a)] Exceeding Temperature Limit During Unusually Warm Years: Surface Area, Acres	Surface Area, Percent[(b)] Near-field	Volume, Acre-ft	Volume, Percent[(b)] Near-field
Maximum for Survival											
Juveniles and adults	96-hr TL50	16.3-26.8	EA 1978b; TI 1976d	<3.7	<0.052	<32.1	<0.022	>141.0	>1.995	>604.0	>0.410
Juveniles	Ult. upper inc. lethal temp.	26.6	EA 1978b	<29.4	<0.415	<321.0	<0.281	>141.0	>1.995	>604.0	>0.410
Minimum Avoidance											
Adults (winter only)	Upper avoidance temp.	9.6-20.0	TI 1976d	<0.6	<0.007	<1.4	<0.001	(c)	(c)	(c)	(c)
Maximum Temperature for Early Development											
Eggs	Upper limit of opt. range for hatch	4.9	EA 1978b	>141.0	>1.995	>604.0	>0.41	(d)	(d)	(d)	(d)
	TL50	6.0-6.9	EA 1978b	<141.0	<1.995	<604.0	<0.41	(d)	(d)	(d)	(d)
Yolk-sac larvae	24-hr TL50	17.8	EA 1978b	0	0	0	0	(d)	(d)	(d)	(d)
Post-yolk-sac larvae	24-hr TL50	16.1	EA 1978b	0	0	0	0	(c)	(c)	(c)	(c)
Optimum for Performance and Growth											
Juveniles (summer)	Final preferendum	10.0	EA 1978b	>29.4	>0.415	>321.0	>0.281	>29.4	>0.415	>321.0	>0.281
Thermal Shock Tolerance											
Plume Entrainment shock											
Eggs											
Tailbud embryo	30-min TL95	20.8	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Eyed-up embryo	30-min TL95	25.3	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Yolk-sac larvae	30-min TL95	23.8-25.7	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Post-yolk-sac larvae	10-min TL95[(e)]	23.2-25.9	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
	30-min TL95	21.1-24.2	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA

(a) Calculations were based on the isotherm exceeding the temperature limit during operation at maximum capacity; areas and volumes are predicted according to actual field surveys conducted when the plant operation load was 93.3-93.8 percent of capacity.

(b) Percent available volume or area based on a near-field area calculated as two tidal excursions (ebb) and flood), one upstream (1.9 miles), and one downstream (3.6 miles); surface area of this near-field area = 7,067 acres, and volume = 146,987 acre-ft.

(c) Temperature limits for high acclimation temperatures are not available.

(d) The maximum area of the thermal plume exceeding temperature requirements for early life stages does not change during unusually warm years, since the occurrence of these life stages is dependent upon spawning temperatures and thus on the timing of spawning.

(e) Data not plotted on Figure 5.3-5.

in the vicinity of Bowline Point during March (Figure 5.3-5) and, therefore, would be potentially susceptible to thermal plume exposures during this time. After March, most tomcod larvae occur in regions downstream of the plant area, though post-yolk-sac larvae are present in relatively low numbers in the vicinity of Bowline Point through mid-May.

Tomcod larvae, like eggs, are very tolerant of high temperatures for short exposure periods. Thirty-minute TL95s for yolk-sac larvae and post-yolk-sac larvae acclimated to 2.5-7.5 C range from 21.1 to 25.7 C (EA 1978b:Table 5.2-5) (Table 5.3-4). These safe temperatures exceed the maximum discharge temperature by several degrees centigrade during winter and early spring months (Figure 5.3-5, lines 12 and 13). Therefore, no mortality resulting from plume entrainment of Atlantic tomcod larvae is likely to occur.

Tomcod larvae are also quite tolerant of exposures to high temperatures for extended periods of time during winter and early spring months. The 24-hour TL50s for yolk-sac larvae and post-yolk-sac larvae are 17.8 C and 16.1 C, respectively, at acclimation temperatures representative of ambient river temperatures during periods of peak abundance (EA 1978b:Table 6.2-3) (Table 5.3-4). These 24-hour TL50s exceed the maximum discharge temperatures during peak abundance (Figure 5.3-5, data points number 5 and 6). Studies on the effects of temperature on the growth and development of tomcod from hatch to advanced post-yolk-sac larvae indicated that the optimum temperature for growth and early development was at least 10.9 C (EA 1978b:Table 9.2-8). Plume temperatures above 10.9 C occur only in the immediate vicinity of the discharge during the period of peak abundance of tomcod larvae in the area of Bowline Point (March) (Figure 5.3-5, line number 10). Therefore, the lower isotherm areas of the thermal plume would not be excluded as suitable habitat for tomcod larvae during periods of peak abundance in the vicinity of Bowline Point.

Atlantic tomcod are concentrated in the lower and middle portions of the estuary throughout spring, summer, and early fall, occurring near the bottom at depths greater than 20 ft (McFadden 1977:p. 6.42). Tomcod are present in the vicinity of Bowline Point from late April through fall, although their abundance decreases in this area after June (Figure 5.3-5).

Since the Atlantic tomcod is a cold-adapted species, it is relatively intolerant of high temperatures during summer months. Incipient lethal temperatures (72- and 96-hour TL50s) for summer-acclimated Atlantic tomcod range from 24.5 C to 26.8 C (Figure 5.3-5, data points number 3a) (EA 1978b:Table 6.2-3). These tolerance limits are exceeded by plume temperatures in areas less than 3.7 acres and volumes less than 32.1 acre-ft (Table 5.3-4). The ultimate upper incipient lethal temperature has been estimated to be 26.6 C (Figure 5.3-5, line number 4) (EA 1978b:p. 6.2-11). The maximum area of the plume exceeding this temperature is less than 29.4 acres; the maximum volume is less than 321.0 acre-ft (Table 5.3-3). Texas Instruments (1976f:pp. V-31 - V-35; 1975b) observed that the growth rate of Atlantic tomcod collected from the Hudson River slowed considerably during high summer temperatures and increased again during the fall as temperatures decreased below approximately 20 C. The final preferendum determined for tomcod collected from the Hudson River estuary during late summer was only 10.0 C (EA 1978b:p. 10.2-9), a temperature much lower than ambient river temperatures. Therefore, the thermal plume would be unsuitable as a habitat for Atlantic tomcod during summer months. Neither the relatively shallow region where the plume occurs nor the upper water stratum where the elevated temperature waters of the plume predominate, however, would normally be utilized as habitat by Atlantic tomcod regardless of temperature because of the species' preference for deeper waters of the estuary.

Sexually mature Atlantic tomcod move into the shore zone of the middle estuary in mid-December to spawn (McFadden 1977:p. 6.46). The spawning population of Atlantic tomcod in the Hudson River estuary is composed almost entirely (>99 percent) of 11- to 13-month-old adults (McFadden 1977:pp. 14.7, 14.9). Impingement collections at the Bowline Point plant show that Atlantic tomcod adults are present in the area of the plant during the winter months (Figure 5.3-5), and are therefore potentially susceptible to thermal plume exposures at this time.

Atlantic tomcod are very tolerant of increased temperatures during the winter. Thermal tolerance limits (96-hour TL50s) range from 16.3 C to 19.9 C for tomcod acclimated to 1.0-3.0 C (EA 1978b:Table 6.2-3; TI 1976d:p. V-40). These tolerance limits exceed the maximum temperatures of the Bowline Point plant's thermal discharge throughout the tomcod spawning season (Figure 5.3-5, data points 3a and 3b). Avoidance temperatures for Atlantic tomcod acclimated to temperatures ranging from 0.5 C to 8.9 C (TI 1976d:pp. V-31 - V-32) occur only in areas of the thermal plume where discharge velocities do not permit residence (Figure 5.3-5, data points number 2). Thus, adult tomcod that may be present within areas influenced by the thermal plume would not be excluded from any major habitat as a result of the elevated temperatures. Consequently, the thermal discharge from the Bowline Point plant would not present an impassable barrier for tomcod migrating upstream to spawn.

Atlantic tomcod that become acclimated to the warmer waters of the thermal plume could be subjected to a sudden decrease in temperature in the event of a plant shutdown. The lower incipient lethal temperature (96-hour TL50) for Atlantic tomcod adults acclimated to 10.0 C is less than 0.2 C (EA 1978b:Table 7.2-1). Since the highest temperature to which a fish can become acclimated in the thermal plume created by the Bowline Point plant is 4.3 C above ambient (maximum habitable isotherm), mortality of Atlantic tomcod as a result of cold shock is not expected to occur.

In summary:

1. The potential for exposure of Atlantic tomcod to the thermal discharge from the Bowline Point plant is predominately limited to late fall and winter months when adults migrate from the deeper areas of the lower estuary to upstream and shore zone areas to spawn, and to late winter and early spring months when larvae are abundant in the vicinity of Bowline Point.
2. Early life stages of tomcod are quite tolerant of short exposures to high temperatures, and mortality is not predicted to occur due to plume entrainment.
3. During peak spawning (January) less than 0.6 acres and 1.4 acre-ft of plume exceed optimum temperatures for normal hatch. However, the entire plume area exceeds optimum temperatures for normal egg hatching success at the extremes of the spawning season. This, however, is of little consequence because of the minimal amount of spawning occurring as far downstream as Bowline Point.
4. Based on the optimum temperature for growth and early development of tomcod larvae and their tolerance to extended thermal exposures, young tomcod would not be adversely affected by the lower isotherms of the thermal plume.

5. Maximum temperatures for survival of spawning adults exceed the maximum discharge temperatures, and temperatures producing an avoidance response occur only in the immediate vicinity of the discharge (0.7 acres and 2.99 acre-ft).
6. The thermal plume would not be expected to create an impassable barrier for migrating adult tomcod.
7. Although the lower isotherm areas of the thermal plume may exceed the upper limit of the temperature range permitting survival and growth of tomcod juveniles during summer months, these plume areas (predominately surface oriented) would not be utilized as habitat by tomcod juveniles regardless of the temperature because of their preference for bottom waters of the estuary at depths greater than 20 ft.
8. There is no potential for cold shock mortalities as a result of total plant shutdown during the winter months.

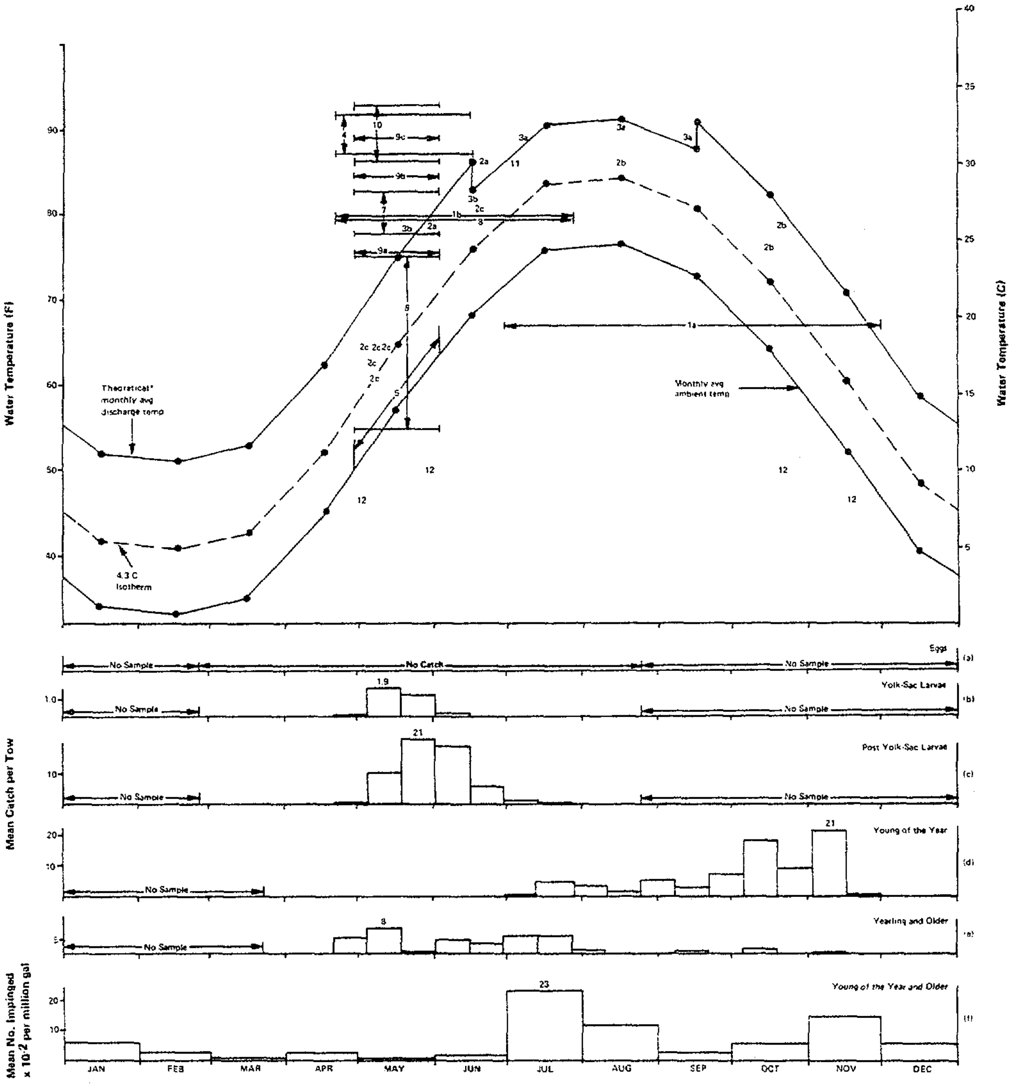
5.3.4.4 Alewife

The alewife (Alosa pseudoharengus) is an anadromous, schooling species indigenous to streams and lakes of the Atlantic coastal drainage of North America from Newfoundland (Scott and Crossman 1973:p. 121) to South Carolina (Mansueti and Hardy 1967:p. 55). Landlocked populations occur in the Great Lakes, the Finger Lakes in New York State, and other freshwater lakes (Scott and Crossman 1973:p. 121). Young alewife serve as food for a variety of predatory fishes, sea birds, and mammals, both in the estuarine nursery areas and at sea. Marine populations of adult alewife are taken commercially and constitute an important sport fishery in coastal rivers and streams during spring spawning migrations. Alewife spend most of their lives at sea (Scott and Crossman

1973:p. 124), utilizing the Hudson River estuary and other coastal river systems as spawning and nursery areas.

In the spring, mature alewife migrate from coastal waters to spawn in tributary streams in the middle and upper regions of the Hudson River estuary, although some spawning occurs along rocky shorelines of the river (TI 1976e: pp. V-67, V-69, V-84). Eggs are broadcast at random over sand or gravel substrates, and are demersal and slightly adhesive (EA 1978a:p. 6-2). Since the principal spawning and nursery area for alewife occurs in the estuary upstream of Bowline Point, the vulnerability of alewife eggs and larvae to thermal plume exposures is quite low. In the vicinity of Bowline Point, clupeid eggs have not been collected in near-field ichthyoplankton samples and yolk-sac larvae occur only in low abundance (Figure 5.3-6).

Early life stages of alewife that encounter the thermal plume created by the Bowline Point plant would not be adversely affected by the elevated temperatures. Eggs and yolk-sac larvae can tolerate 5-minute exposures, and, in most cases, 30-minute exposures to temperatures much higher than the theoretical maximum discharge temperatures during the alewife spawning season (EA 1978b: Tables 5.2-6 and 5.2-7) (Figure 5.3-6, data points number 9 and 10) (Table 5.3-5). Advanced post-yolk-sac larvae can tolerate temperatures of 29.1-30.3 C (TL95s) for 5- and 30-minute exposures at acclimation (ambient) temperatures of 20.0 C and 22.5 C (EA 1978b:Table 5.2-7) (Table 5.3-5). Although theoretical maximum discharge temperatures slightly exceed these tolerance limits (Figure 5.3-6, data point number 11), it is unlikely that mortality of post-yolk-sac larvae would occur as a result of entrainment into the warmest portion of the thermal plume because of the extremely short exposure time (5-10 seconds). Therefore, mortality of alewife eggs and larvae is not predicted



*Assumes continual plant operation at maximum capacity.

Key to Thermal Effects Data Points

1. 19.5-26.5 C, final preferendum; (a) young of the year, EA 1978b, (b) advanced post-yolk-sac larvae, EA 1978b.
2. *16.0-30.0 C, upper avoidance temps.; (a) adults, EA 1978b;* (b) young of the year, Meldrim and Gift 1971; (c) adults, TI 1973.
3. 25.5-32.6 C, upper incipient lethal temps. (96-hr TL50), (a) young of the year, (b) adults; EA 1978b.
4. 30.7-33.5 C, range of 24-hr TL50s for yolk-sac larvae; EA 1978b.
5. 10.0-17.5 C, normal spawning range; TI 1976e.
6. 12.7-23.9 C, optimum range for normal hatch; EA 1978b.
7. 25.4-28.2 C, range of TL50s for normal hatch; EA 1978b.
8. 26.4 C, optimum temp. for net biomass gain for development from hatch through post-yolk-sac stage; EA 1978b.
9. 24.2-31.7 C, 30-min TL95s for eggs: (a) blastula stage, (b) tail-bud embryo stage, (c) tail-free embryo stage; EA 1978b.
10. 30.1-33.8 C, range of 30-min TL95s for yolk-sac larvae (1-day-old); EA 1978b.
11. 30.1 C, 30-min TL95 for advanced post-yolk-sac larvae; EA 1978b.
12. 8.0-10.0 C, lower incipient lethal temps. (TL60 + 2C) for adults; Otto et al. 1976.

Key to Seasonal Distribution Histograms

(a) Mean no. Clupeidae eggs collected in 5-min plankton tows for 1974-1976, RM 37; TI 1975a, TI 1976a, TI 1977.
(b) *Mean no. Clupeidae yolk-sac larvae collected in 5-min plankton tows* for 1974-1976, RM 37; TI 1975a, TI 1976a, TI 1977.
(c) Mean no. Clupeidae post-yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 37, TI 1975a, TI 1976a, TI 1977.
(d) Mean no. young of the year alewife collected in beach seines for 1974-1975, RM 36-37; TI 1976b, TI 1976c.
(e) Mean no. yearling and older alewife collected in beach seines for 1974-1975, RM 36-37; TI 1976b, TI 1976c.
(f) Mean no. young of the year and older alewife from impingement collections 1973-1976; Orange and Rockland 1977.

Figure 5.3-6. Thermal effects diagram for alewife at the Bowline Point Generating Station on the Hudson River

TABLE 5.3-5 THERMAL EFFECTS SUMMARY TABLE FOR ALEWIFE

				Maximum Area of Thermal Plume(a) Exceeding Temperature Limit During Typical Years				Maximum Area of Thermal Plume(a) Exceeding Temperature Limit During Unusually Warm Years			
				Surface Area		Volume		Surface Area		Volume	
Biological Activity To Be Protected	Thermal Effects Parameter	Temp. Limit or Range (C)	Reference	Acres	Percent(b) Near-field	Acre-ft	Percent(b) Near-Field	Acres	Percent(b) Near-field	Acre-ft	Percent(b) Near-field
Maximum for Survival											
Adults	96-hr TL50	25.5-28.4	EA 1978b	<0.6	<0.007	<1.4	<0.001	(c)	(c)	(c)	(c)
Juveniles	96-hr TL50	31.7-32.6	EA 1978b	<0.7	<0.010	<2.99	<0.002	<0.7	<0.010	<2.99	<0.002
Minimum Avoidance											
Juveniles	Upper avoidance temp.	24.0-30.0	Meldrim & Gift 1971	<0.7	<0.010	<2.99	<0.002	<3.7	<0.052	<32.10	<0.022
Adults	Upper avoidance temp.	16.0-30.0	TI 1973; EA 1978b	<0.6	<0.007	<1.4	<0.001	(c)	(c)	(c)	(c)
Maximum Temperature for Early Development											
Eggs	Upper limit of opt. range for hatch	23.9	EA 1978b	<0.6	<0.007	<1.4	<0.001	(d)	(d)	(d)	(d)
	TL50	25.4-28.2	EA 1978b	<0.6	<0.007	<1.4	<0.001	(d)	(d)	(d)	(d)
Yolk-sac larvae	24-hr TL50	30.7-33.5	EA 1978b	0	0	0	0	(d)	(d)	(d)	(d)
Optimum for Performance and Growth											
Larvae	Opt. temp. for net biomass gain	26.4	EA 1978b	<0.6	<0.007	<1.4	<0.001	141.0	1.995	604.0	0.41
Juveniles	Final preferendum	19.5	EA 1978b	>141.0	>1.995	>604.0	>0.41	>141.0	>1.995	>604.0	>0.41
Thermal Shock Tolerance											
Cold Shock											
Adults	Lower inc. lethal temp. + 2.0 C	8.0-10.0	Otto et al 1976	NA	NA	NA	NA	NA	NA	NA	NA

(a) Calculations were based on the isotherm exceeding the temperature limit during operation at maximum capacity; areas and volumes are predicted according to actual field surveys conducted when the plant operation load was 93.3-93.8 percent of capacity.

(b) Percent available volume or area based on a near-field area calculated as two tidal excursions (ebb) and flood), one upstream (1.9 miles), and one downstream (3.6 miles); surface area of this near-field area = 7,067 acres, and volume = 146,987 acre-ft.

(c) Temperature limits for high acclimation temperatures are not available.

(d) The maximum area of the thermal plume exceeding temperature requirements for early life stages does not change during unusually warm years, since the occurrence of these life stages is dependent upon spawning temperatures and thus on the timing of spawning.

Note: NA = not applicable.

TABLE 5.3-5 (CONT.)

Biological Activity To Be Protected	Thermal Effects Parameter	Temp. Limit or Range (C)	Reference	Maximum Area of Thermal Plume(a) Exceeding Temperature Limit During Typical Years				Maximum Area of Thermal Plume(a) Exceeding Temperature Limit During Unusually Warm Years			
				Surface Area		Volume		Surface Area		Volume	
				Acres	Percent(b) Near-field	Acre-ft	Percent(b) Near-Field	Acres	Percent(b) Near-field	Acre-ft	Percent(b) Near-field
Plume Entrainment Shock											
Eggs											
Blastula stage	5-min TL95(c)	28.3	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Blastula stage	30-min TL95	24.2	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Tailbud embryo	30-min TL95	29.2	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Tail-free embryo	30-min TL95	31.7	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Yolk-sac larvae	30-min TL95	30.1-33.8	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Advanced post-yolk-sac larvae	5-min TL95(c)	29.1-30.3	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
	30-min TL95	30.1	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA

(a) Calculations were based on the *isotherm exceeding* the temperature limit during operation at maximum capacity; areas and volumes are predicted according to actual field surveys conducted when the plant operation load was 93.3-93.8 percent of capacity.

(b) Percent available volume or area based on a near-field area calculated as two tidal excursions (ebb) and flood), one upstream (1.9 miles), and one downstream (3.6 miles); surface area of this near-field area = 7,067 acres, and volume = 146,987 acre-ft.

(c) Data not plotted on Figure 5.3-6.

Note: NA = not applicable.

to occur as a result of either short-term or extended exposures to plume temperatures.

Early life stages of alewife are also tolerant of extended exposures to elevated temperature. Twenty-four-hour TL50s for yolk-sac larvae acclimated to temperatures representative of those occurring during peak abundance range from 30.7 to 33.5 C (EA 1978b:Table 6.2-4). These tolerance limits exceed the maximum discharge temperatures during peak abundance (Figure 5.3-6, line number 4). Thus, yolk-sac larvae, when found in the Bowline Point vicinity, would be capable of tolerating extended exposures to elevated plume temperatures.

The optimum temperature for growth and early development of alewife, as approximated by the optimum temperature for net biomass gain (combination of optima for survival and growth), is 26.4 C (EA 1978b:p. 9.2-24) (Figure 5.3-6, line number 8). This temperature is exceeded by plume temperatures only within the immediate vicinity of the discharge (<0.6 acres and 1.4 acre-ft) during May and June. Although the exclusion area increases during the midsummer months, few clupeid larvae occur in the vicinity of the plant during this time. Ambient river temperatures during the spring and early summer are commonly lower than the optimum temperature for growth and early development of alewife.

Young-of-the-year alewife increase in abundance in the vicinity of Bowline Point throughout the summer and fall as they migrate downstream toward the sea, and are the most susceptible to thermal plume exposures during peak abundance in October and November (Figure 5.3-6). The upper limit of the temperature range permitting survival of juvenile alewife is 31.7-32.6 C (96-hour TL50), depending on acclimation (ambient) temperatures (EA 1978b:Table 6.2-4)

(Table 5.3-5). Plume temperatures higher than these tolerance limits occur only in the immediate vicinity of the discharge where velocities are too high to allow extended exposure (Figure 5.3-6, data points number 3a). The maximum area of the discharge that would be potentially avoided because of high temperatures, based on avoidance temperatures of 26.0-30.0 C reported by Meldrim and Gift (1971:p. 34), is less than 0.7 acres and 2.99 acre-ft (Table 5.3-5), and similarly occurs only in the immediate vicinity of the discharge (Figure 5.3-6, data points 2a). Therefore, alewife juveniles migrating shoreward and downstream during late summer and fall would not be excluded from any major habitat in the vicinity of Bowline Point because of the elevated temperatures.

The optimum temperature for growth and performance of juvenile alewife, as approximated by the final preferendum, is 19.5 C (EA 1978b:p. 10.2-11). This final preferendum is exceeded by ambient river temperatures throughout the summer and early fall (Figure 5.3-6, line number 1a). However, since final preferenda only estimate some point within the optimum temperature range, satisfactory growth and performance may occur at even higher temperatures. Assuming that the optimum temperature for net biomass gain of advanced post-yolk-sac larvae, 26.4 C, is a better estimate of the upper limit of the optimum temperature for growth of juvenile alewife, the maximum area of the plume exceeding this limit is approximately 29.4 acres and 321.0 acre-ft during the summer (Table 5.3-5). This area decreases to less than 0.6 acres and 1.4 acre-ft by mid-September when alewife juveniles begin to become abundant in the vicinity of Bowline Point. Because the alewife population in the vicinity of Bowline Point is transitory, it is unlikely that any differences in growth would be observed for alewife occuring in the area of the plant.

Since alewife adults move downstream and return to sea soon after spawning (Bigelow and Schroeder 1953:p. 103), they are predominately susceptible to thermal plume exposures only during April and May. The 96-hour TL50s for adult alewife during spring months range from 25.5 C to 28.4 C, depending on acclimation (ambient) temperatures (EA 1978b:Table 6.2-4). These tolerance limits exceed temperatures in all areas of the plume except for the immediate vicinity of the discharge where velocities are too high to allow extended exposure (Figure 5.3-6, data points number 3b). Temperatures that would be potentially avoided by migrating adults range from 16.0 C to 30.0 C, depending on acclimation (ambient) temperature (EA 1978b:Table 10.2-4; TI 1973: pp. IV-23 - IV-24), and would similarly occur only in the immediate vicinity of the discharge (Figure 5.3-6, data points number 2b and 2c). Thus, alewife adults migrating to upstream areas of the estuary to spawn would not be excluded from plume areas greater than 0.7 acres and 2.99 acre-ft because of the warm temperatures (Table 5.3-5). As a result, the thermal plume created by the Bowline Point plant would not be expected to block alewife spawning migrations.

Alewife that become acclimated to the warmer waters of the thermal plume could be subjected to a sudden decrease in temperature in the event of a plant shutdown. The lower tolerance limits for adult alewife acclimated to 15.0 C and 21.0 C are 8.0 C and 10.0 C, respectively (lower incipient lethal temperature plus 2.0 C) (Otto et al. 1976:p. 102), These represent temperature decreases of 7.0 C and 11.0 C. Since the highest temperature to which a fish can become acclimated in the thermal plume created by the Bowline Point plant is 4.3 C above ambient (maximum habitable isotherm), mortality of alewife is not predicted to occur because of cold shock (Figure 5.3-6, data points number 12).

In summary:

1. Exposure of alewife to the thermal plume created by the Bowline Point plant is predominately limited to spring months when adults migrate to upstream areas of the estuary to spawn, and to late summer and early fall months when the young migrate downstream to the sea.
2. Whereas early life stages occur predominately in upstream nursery areas, eggs and larvae that may be present in the vicinity of Bowline Point would suffer little or no appreciable harm because of plume entrainment or because of extended exposures to the lower temperature plume areas.
3. Maximum temperatures for survival and upper avoidance temperatures for juveniles and adults are normally exceeded only in the immediate vicinity of the discharge where high velocities prevent extended exposure.
4. Alewife should not be excluded from any major habitat in the vicinity of Bowline Point, nor should the elevated temperatures block upstream spawning migrations.
5. No mortalities resulting from cold shock in the event of a plant shutdown are predicted to occur.
6. Optimum temperatures for growth and performance are exceeded only in the high velocity-high temperature areas of the plume where extended exposure is restricted.

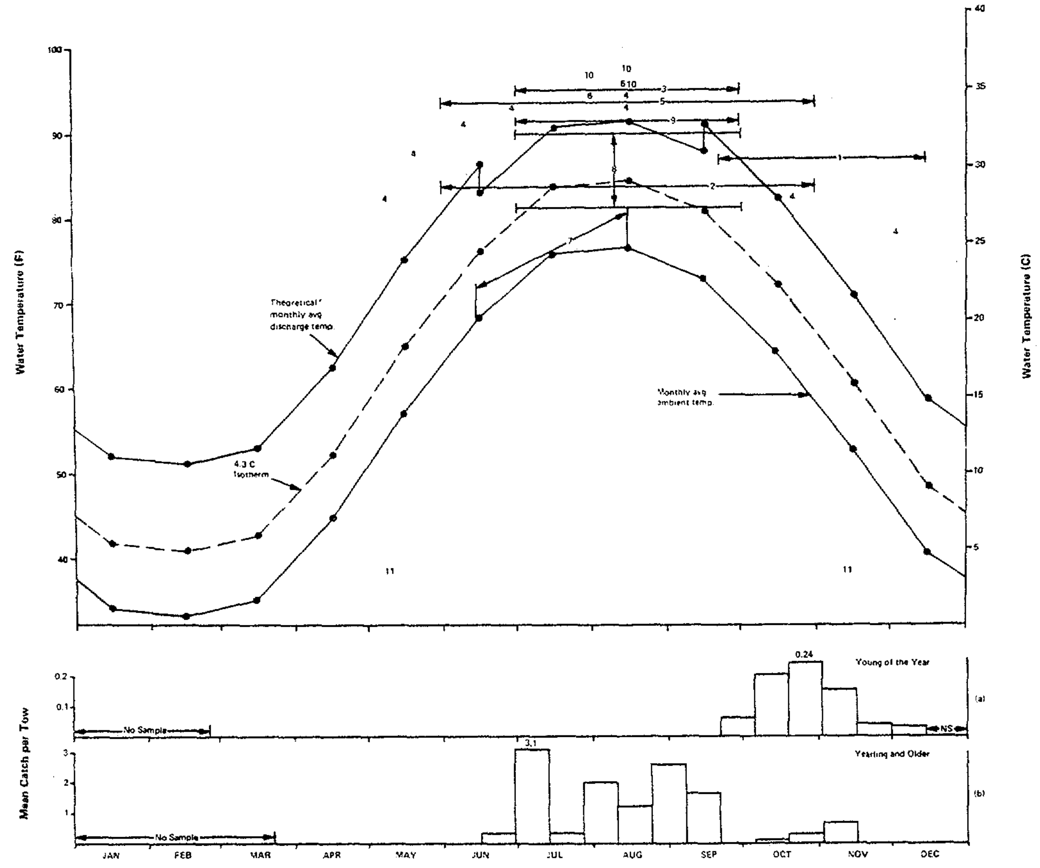
5.3.4.5 White Catfish

The white catfish (*Ictalurus catus*) is endemic to coastal streams and rivers from Massachusetts south to Florida, and west along the Gulf Coast to the Escambia drainage (Mansueti and Hardy 1967:p. 161; Carlander 1969:p. 519). It is a year-round resident within the tidal portion of the Hudson River estuary, but is not abundant.

White catfish are predominately bottom-dwellers during all life stages, inhabiting both fresh and brackish waters up to a maximum salinity of 14.5 ppt (Kendall and Schwartz 1968:pp. 106-107). They spawn during late spring and early summer when temperatures increase above 20 C (Turner and Kelley 1966: p. 135), depositing their eggs in adhesive masses within circular depressions on the river bottom (Miller 1966:p. 432). The eggs and young are closely guarded by the parents and travel in dense schools until the end of the first summer (Breder and Rosen 1966:p. 258; Mansueti and Hardy 1967:p. 161). In the Connecticut River, Marcy (1976:pp. 89-90) observed that white catfish overwintered in the tributaries, coves, and attached ponds, returning to the main river in early spring where they remained throughout the summer and fall. White catfish occur in the vicinity of Bowline Point from late June through November (Figure 5.3-7), and are minimally exposed to the surface-oriented thermal plume because of their bottom-dwelling habit.

Early life stages of white catfish are very tolerant of high temperatures. Thirty-minute TL95s for post-yolk-sac larvae and early juveniles acclimated to 24.5-25.0 C range from 35.0 to 36.3 C (EA 1978b:Table 5.2-8) (Table 5.3-6). Since these temperatures exceed maximum discharge temperatures during peak abundance, the potential for plume entrainment mortality is negligible (Figure 5.3-7, data points number 10).

White catfish larvae and early juveniles are also tolerant of longer exposures to elevated temperature. Twenty-four-hour TL50s range from 34.6 C to 35.4 C (EA 1978b:Table 6.2-5). These thermal tolerance limits exceed maximum discharge temperatures at the Bowline Point plant during warm summer months



*Assumes continual plant operation at maximum capacity.

Key to Thermal Effects Data Points

1. 30.5 C, final preferendum for young of the year; EA 1978b.
2. 28.7 C, final preferendum for adults; EA 1978b.
3. 35.0 C, field avoidance temp. for adults, Marcy 1976.
4. 25.6-34.7 C, upper incipient lethal temp. for juveniles and adults (96-hr TL50); EA 1978b.
5. 34.2 C, ultimate upper incipient lethal temp. for adults; EA 1978b.
6. 34.6-35.4 C, 24-hr TL50 for post-yolk-sac larvae and early juveniles; EA 1978b.
7. 20-26.0 C, normal spawning temp.; Turner and Kelly 1966, EA 1978b.
8. 27.3-32.2 C, optimum range for growth from post-yolk-sac larvae to juveniles; EA 1978b.
9. 33.0 C, ultimate upper incipient lethal temp. for post-yolk-sac larvae and early juveniles (21-day TL50); EA 1978b.
10. 35-36.3 C, 30-min TL95 for post-yolk-sac larvae and early juveniles; EA 1978b.
11. 3.6 C, lower incipient lethal temp. for juveniles (96-hr TL50 + 2 C); EA 1978b.

Key to Seasonal Distribution Histograms

(a) Mean no. young of the year collected in 5-min plankton tows for 1974-1976, RM 36-37; TI 1975a, TI 1976a, TI 1977.

(b) Mean no. yearling and older collected in beach seines for 1974-1975, RM 36-37; TI 1976b, TI 1976c.

Figure 5.3-7. Thermal effects diagram for white catfish at the Bowline Point Generating Station on the Hudson River.

TABLE 5.3-6 THERMAL EFFECTS SUMMARY TABLE FOR WHITE CATFISH

				Maximum Area of Thermal Plume[a] Exceeding Temperature Limit During Typical Years				Maximum Area of Thermal Plume[a] Exceeding Temperature Limit During Unusually Warm Years			
				Surface Area		Volume		Surface Area		Volume	
Biological Activity To Be Protected	Thermal Effects Parameter	Temp. Limit or Range (C)	Reference	Acres	Percent[b] Near-field	Acre-ft	Percent[b] Near-Field	Acres	Percent[b] Near-field	Acre-ft	Percent[b] Near-field
Maximum for Survival											
Juveniles and Adults	96-hr TL50	25.6-34.7	EA 1978b	0	0	0	0	<0.7	<0.01	<2.99	<0.002
Adults	Ult. upper inc. lethal temp.	34.2	EA 1978b	0	0	0	0	<0.7	<0.01	<2.99	<0.002
Minimum Avoidance											
Adults	Field avoidance temp.	35.0	Marcy 1976	0	0	0	0	<0.7	<0.01	<2.99	<0.002
Maximum Temp. for Early Development											
Post-yolk-sac larvae and early juveniles	24-hr TL50	34.6-35.4	EA 1978b	0	0	0	0	<0.07	<0.01	<2.99	<0.002
Post-yolk-sac larvae and early juveniles	Ult. upper inc. lethal temp.	33.0	EA 1978b	0	0	0	0	<0.7	<0.01	<2.99	<0.002
Optimum for Performance and Growth											
Post-yolk-sac larvae and early juveniles	Upper limit of opt. temp. for growth	32.2	EA 1978b	<0.7	<0.01	<2.99	<0.002	<0.7	<0.01	<2.99	<0.002
Adults	Final preferendum	28.7	EA 1978b	<0.7	<0.01	<2.99	<0.002	<141.0	<1.995	<604.0	<0.41
Young-of-the-year	Final preferendum	30.5	EA 1978b	<0.7	<0.01	<2.99	<0.002	<0.7	<0.01	<2.99	<0.002
Thermal Shock Tolerance											
Cold Shock											
Juveniles	TL50 + 2 C	3.6	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Plume Entrainment Shock											
Post-yolk-sac larvae and early juveniles	30-min TL95	35.0-36.3	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA

(a) Calculations were based on the isotherm exceeding the temperature limit during operation at maximum capacity; areas and volumes are predicted according to actual field surveys conducted when the plant operation load was 93.3-93.8 percent of capacity.

(b) Percent available volume or area based on a near-field area calculated as two tidal excursions (ebb) and flood), one upstream (1.9 miles), and one downstream (3.6 miles); surface area of this near-field area = 7,067 acres, and volume = 146,987 acre-ft.

Note: NA = not applicable.

(Figure 5.3-7, line number 6). Furthermore, the ultimate incipient lethal temperature for young white catfish, 33.0 C (21-day TL50) (EA 1978b:p. 9.2-29), is exceeded by plume temperatures only in the immediate vicinity of the discharge, where velocities do not permit extended exposures (Figure 5.3-7, line number 9) (Table 5.3-6). Plume temperatures exceeding the upper limit of the optimum temperature for growth of post-yolk-sac larvae and early juveniles, 32.2 C (EA 1978b:p. 9.2-24), similarly occur only in the immediate vicinity of the discharge (Figure 5.3-7, line number 8). Therefore, no major habitat influenced by the thermal plume from the Bowline Point plant would impair the survival or growth of young white catfish.

Older white catfish are equally tolerant of high temperatures. Ninety-six-hour TL50s range from 25.6 C to 34.7 C for juveniles and adults acclimated to 7.5-26.0 C (EA 1978b:Table 6.2-5) (Figure 5.3-7, data points number 4). These exceed maximum discharge temperatures throughout the year (Table 5.3-6). The ultimate incipient lethal temperature for adult white catfish, 34.2 C (EA 1978b:p. 6.2-19), also exceeds maximum discharge temperatures (Figure 5.3-7, line number 5) (Table 5.3-6). In the Connecticut Yankee Atomic Plant discharge canal (Connecticut River), Marcy (1976:pp. 90-91) observed that white catfish did not appear to avoid the warm discharge waters until temperatures increased above 35.0 C. Therefore, bottom areas in the vicinity of Bowline Point that may be influenced by the thermal plume should not be excluded as suitable habitat for white catfish.

The optimum temperatures for performance and growth of young-of-the-year and adult white catfish, as approximated by the final preferenda, are 30.5 C and 28.7 C, respectively (EA 1978b:p. 10.2-15). These temperatures would seldom be exceeded by the habitable isotherms of the thermal plume (<4.3 C) (Figure

5.3-7, lines number 1, 2a, and 2b) (Table 5.3-6). Thus, white catfish that may reside within areas influenced by the thermal discharge from the Bowline Point plant would not be adversely affected by the warm temperatures.

White catfish that may become acclimated to the warmer waters of the thermal plume could be subjected to a sudden decrease to ambient river temperatures in the event of a plant shutdown. The lower tolerance limit for white catfish acclimated to 16.5 C is 3.6 C (96-hour TL50 + 2 C) (EA 1978b:Table 7.2-1). This lower tolerance limit represents a temperature decrease of 12.9 C below acclimation temperatures (Figure 5.3-7, data point number 11). Since the highest temperature to which a fish can become acclimated in the thermal plume is 4.3 C above ambient, the potential for cold shock mortality of white catfish is quite low. In addition, white catfish densities clearly decline during the late fall months to low winter levels (Figure 5.3-7), further minimizing the potential for cold shock.

In summary:

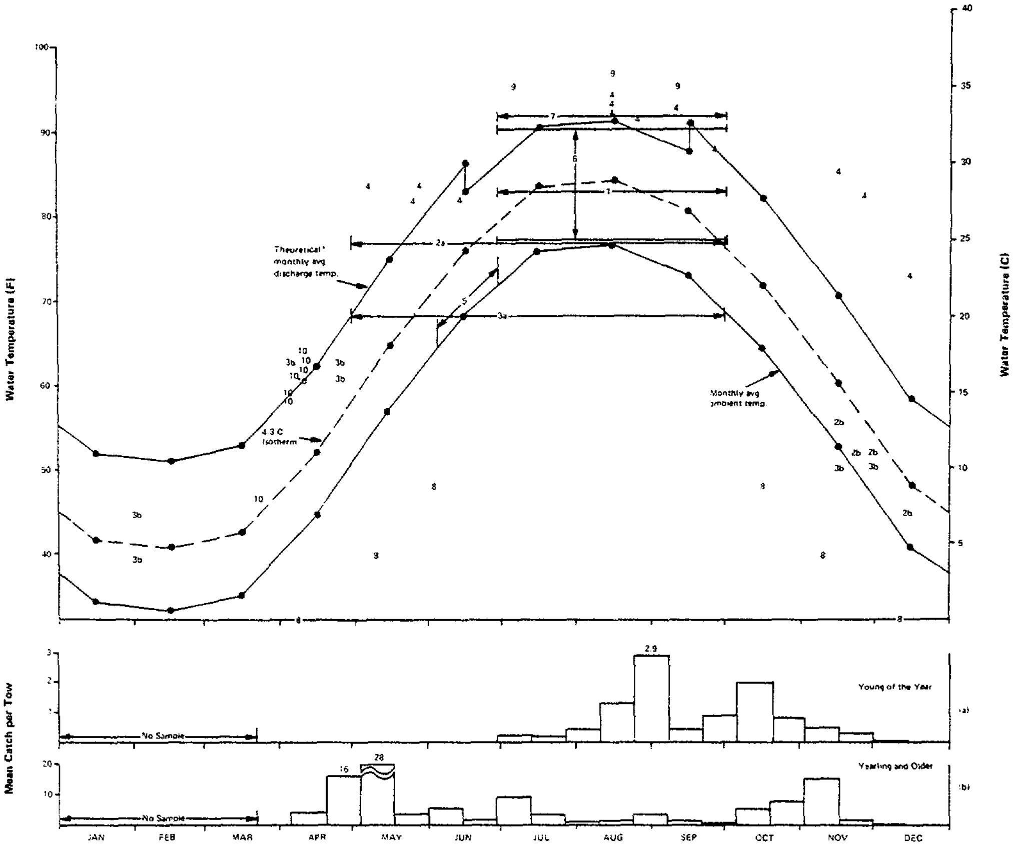
1. White catfish are potentially susceptible to thermal plume exposures throughout the summer and fall months, although exposures would be limited to the lower plume isotherms because of their preference for bottom areas and because of the surface orientation of the thermal plume.
2. All life stages are very tolerant of high temperatures, and would not be excluded from any portion of the thermal plume likely to extend to the bottom.
3. Mortality resulting from plume entrainment should not occur.
4. The potential for mortality of white catfish as a result of cold shock in the event of a plant shutdown is minimal.

5.3.4.6 Spottail Shiner

The spottail shiner (Notropis hudsonius) occurs in North America from sections of Canada southward in the United States, to Georgia in the east, and to Iowa and Missouri in the west (Scott and Crossman 1973:p. 460). Although not of commercial importance, it is occasionally used as bait and serves as prey for larger fish. The spottail shiner is a year-round resident in the Hudson River estuary.

Spottail shiners inhabit the shore zone areas of the Hudson River estuary throughout the spring, summer, and fall, moving offshore into deeper water during winter months (TI 1976e:pp. V-124, V-126). They are most abundant in fresh or slightly brackish waters upstream of the Bowline Point plant (TI 1976e:p. V-124). Spottail shiners spawn in spring and early summer. Similar to other cyprinids, the eggs are demersal and strongly adhesive, and, therefore, would not be vulnerable to plume entrainment exposures. Major concentrations of juveniles occur between Hyde Park and Albany (MP 77-152) (TI 1976e:p. 126), indicating that this section of the river is a major nursery area and possibly a principal spawning ground. Young-of-the-year spottail shiners are present in the vicinity of Bowline Point (MP 37.5) in relatively low abundance during late summer and early fall, while adults occur in larger numbers primarily during spring and fall months (Figure 5.3-8). During this time, they would potentially be exposed to the lower temperature isotherms of the thermal plume that intermittently influence the shore zone areas, varying with the tidal currents and wind.

Young spottail shiners are quite tolerant of high temperatures. Thirty-minute TL95s for early juveniles acclimated to 23.0-26.0 C range from 35.0 to 35.8 C (EA 1978b:Table 5.2-9). These safe temperatures exceed maximum cooling water



*Assumes continual plant operation at maximum capacity.

Key to Thermal Effects Data Points

1. 28.2 C, final preferendum for <50 mm, May-September: EA 1978b.
2. 7.0-24.8 C, final preferendum for 50-90 mm, (a) May-September, (b) October-April: EA 1978b.
3. 4.0-20.1 C, final preferendum for >90 mm, (a) May-September, (b) October-April: EA 1978b.
4. 22.6-34.4 C, upper incipient lethal temp. for juveniles and adults (96-hr TL50); EA 1978b.
5. 18.0-22.0 C, normal spawning temp.; EA 1978b.
6. 25.0-32.2 C, optimum range for growth of early juveniles; EA 1978b.
7. 33.1 C, ultimate upper incipient lethal temp. for early juveniles (21-day TL50); EA 1978b.
8. 0.0-8.7 C, lower incipient lethal temp. for juveniles and adults (96-hr TL50 + 2C); EA 1978b.
9. 35.0-35.8 C, 30-min TL95s for early juveniles: EA 1978b.
10. 8.0-17.8 C, upper avoidance temps. for adults: TI 1973.

Key to Seasonal Distribution Histograms

(a) Mean no. young of the year collected in beach seines for 1974-1975, RM 36-37; TI 1976b, TI 1976c.

(b) Mean no. yearling and older collected in beach seines for 1974-1975, RM 36-37; TI 1976b, TI 1976c.

Figure 5.3-8. Thermal effects diagram for spottail shiner at the Bowline Point Generating Station on the Hudson River.

discharge temperatures from the Bowline Point plant during warm summer months (Figure 5.3-8, data points number 9). Furthermore, the ultimate incipient lethal temperature for young spottail shiner, 33.1 C (21-day TL50) (EA 1978b: p. 9.2-29), similarly exceeds these discharge temperatures (Figure 5.3-8, line number 7) (Table 5.3-7). The upper limit of the optimum temperature range for growth of young spottail shiners has been determined to be 32.2 C (EA 1978b: p. 9.2-29). The maximum area and volume of the thermal plume with temperatures greater than 32.2 C are less than 0.7 acres and 2.99 acre-ft, respectively (Figure 5.3-8, line number 6) (Table 5.3-7). Since plume temperatures exceeding these upper limits for survival and growth occur only in areas where discharge velocities do not permit extended exposure, temperatures within plume areas normally occupied by young spottail shiner in the vicinity of Bowline Point would not impair their survival or growth.

Older juveniles and adults are equally tolerant of high temperatures. Upper incipient lethal temperatures (96-hour TL50s) range from 22.6 C to 34.4 C for spottail shiners acclimated to 5.0-26.0 C (EA 1978b:Table 6.2-6). These thermal tolerance limits are exceeded by plume temperatures only in the immediate vicinity of the discharge where high velocities do not permit residence (Figure 5.3-8, data points number 4). The maximum area of the discharge that would be potentially avoided because of high temperatures during spring months, based on avoidance temperatures reported by TI (1973:pp. IV-19, IV-22), is less than 0.6 acres and 1.4 acre-ft (Figure 5.3-8, data points number 10) (Table 5.3-7). Thus, shore zone areas in the vicinity of Bowline Point that may be influenced by the thermal plume would not be excluded as suitable habitat for spottail shiners.

TABLE 5.3-7 THERMAL EFFECTS SUMMARY TABLE FOR SPOTTAIL SHINER

				Maximum Area of Thermal Plume[a] Exceeding Temperature Limit During Typical Years				Maximum Area of Thermal Plume[a] Exceeding Temperature Limit During Unusually Warm Years			
				Surface Area		Volume		Surface Area		Volume	
Biological Activity To Be Protected	Thermal Effects Parameter	Temp. Limit or Range (C)	Reference	Acres	Percent[b] Near-field	Acre-ft	Percent[b] Near-Field	Acres	Percent[b] Near-field	Acre-ft	Percent[b] Near-field
Maximum for Survival											
Juveniles and adults	96-hr TL50	22.6-34.4	EA 1978b	<0.6	<0.007	<1.4	<0.001	<0.7	<0.010	<2.99	<0.002
Minimum Avoidance											
Adults (early spring)	Upper avoidance temp.	8.0-17.8	TI 1973	<0.6	<0.007	<1.4	<0.001	(c)	(c)	(c)	(c)
Maximum Temperature for Early Development											
Early juveniles	Ult. upper inc. lethal temp.	33.1	EA 1978b	0	0	0	0	<0.7	<0.010	<2.99	<0.002
Optimum for Performance and Growth											
Early juveniles	Upper limit of opt. temp. range for growth	32.2	EA 1978b	<0.7	<0.01	<2.99	<0.002	<0.7	<0.01	<2.99	<0.002
Adults and juveniles (May-September)											
50-90 mm	Final preferendum	24.8	EA 1978b	>141.0	>1.995	>604.0	>0.410	>141.0	>1.995	>604.0	>0.410
>90 mm	Final preferendum	20.1	EA 1978b	>141.0	>1.995	>604.0	>0.410	>141.0	>1.995	>604.0	>0.410
Thermal Shock Tolerance											
Cold Shock											
Adults and juveniles	96-hr TL50 + 2 C	0.0-8.7	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Plume Entrainment											
Early juveniles	30-min TL95	35.0-35.8	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA

(a) Calculations were based on the isotherm exceeding the temperature limit during operation at maximum capacity; areas and volumes are predicted according to actual field surveys conducted when the plant operation load was 93.3-93.8 percent of capacity.

(b) Percent available volume or area based on a near-field area calculated as two tidal excursions (ebb) and flood), one upstream (1.9 miles), and one downstream (3.6 miles); surface area of this near-field area = 7,067 acres, and volume = 146,987 acre-ft.

(c) Temperature limits for high acclimation temperatures are not available.

Note: NA = not applicable.

Final preferenda of spottail shiners vary according to size and season (EA 1978b:pp. 10.2-15 - 10.2-17). During the cooler times of the year, the final preferenda are typically equal to or slightly higher than ambient river temperatures. However, during the summer, ambient river temperatures often exceed the final preferenda (Figure 5.3-8, lines 1, 2a, and 3a, and points 2b and 3b). Since spottail shiners are often abundant in the shore zones of the estuary where temperatures are typically warmer than in the deeper channel areas, it is possible that these final preferenda do not estimate the upper limit of the optimum temperature for performance and growth in the case of spottail shiner.

Spottail shiners that may become acclimated to the warmer waters of the thermal plume could be subjected to a sudden decrease to ambient river temperatures in the event of a plant shutdown. Adults and juveniles can tolerate temperature decreases of at least 10.0 C below acclimation temperatures, even to a lower temperature of 0.0 C (EA 1978b:Table 7.2-1) (Figure 5.3-8, points number 8). Since the highest temperature to which a fish can become acclimated in the thermal plume is 4.3 C above ambient (maximum habitable isotherm), no mortality of spottail shiner is predicted due to cold shock.

In summary:

1. Juvenile and adult spottail shiners are potentially susceptible to thermal plume exposures throughout most of the year, although exposures are limited as a result of the concentration of spottail shiners in areas upstream of the Bowline Point and their preferences for shore zone areas.

2. Spottail shiners are very tolerant of high temperatures, and would not be excluded from any portion of the thermal plume that may occur in shore zone areas based on temperature requirements for survival.
3. Mortality would not occur as a result of plume entrainment or cold shock.
4. Although shore zone areas that may be influenced by the thermal plume would not be excluded as suitable habitat for young spottail shiners, the final preferendum for adults is exceeded by most plume areas.

5.3.4.7 Atlantic and Shortnose Sturgeon

The Atlantic sturgeon (*Acipenser oxyrhynchus*) and the shortnose sturgeon (*A. brevirostrum*) are distributed along the Atlantic Coast of North America from Canada to Florida. During the late 1800s, Atlantic sturgeon constituted a significant commercial fishery in the Hudson River; however, their abundance declined considerably in the early 1900s (Scott and Crossman 1973:p. 95). Although the fishery has shown recovery in recent years, commercial catches in the United States are only about half as large as those of the 1880s. The shortnose sturgeon is of little commercial importance because of its small size and relative scarcity throughout its range. The U.S. Department of Interior has placed the shortnose sturgeon on its list of endangered species.

Atlantic sturgeon are anadromous, migrating into freshwater areas of tidal rivers and estuaries to spawn in the spring (Bigelow and Schroeder 1953). In the Hudson River, mature adults enter the estuary to spawn from April through June (Boyle 1969:p. 201; Greeley 1937:p. 68), and have been collected in freshwater portions of the estuary between Highland and Saugerties (MP 76-101) (Greeley 1937:p. 68). After hatching, the young remain in freshwater for several years before going to sea (Scott and Crossman 1973:p. 94). During 1973 fishery surveys in the Hudson River estuary, juvenile Atlantic sturgeon were predominately collected in areas upstream of the Bowline Point plant (TI 1976e:p. V-96).

The shortnose sturgeon, which is less migratory than the Atlantic sturgeon, spends most of its life in fresh and brackish waters of large tidal rivers, but has been collected in saltwater (Scott and Crossman 1973:p. 81; Dadswell 1975:pp. 17, 20). Adults apparently spawn in deep, turbulent regions of main river channels during the spring at temperatures of approximately 10 C (Dadswell 1975: pp. 12-13; Greeley 1937:p. 90). Dadswell (1975:pp. 17-20) observed a seasonal migration pattern for shortnose sturgeon in the St. John estuary, New Brunswick. He reported that shortnose sturgeon overwintered in the deeper saline regions of the lower estuary, moving into the main channel areas in the spring to spawn, and migrated upstream and shoreward during summer months. In the Hudson River estuary, shortnose sturgeon have been collected in the Tappan Zee to Kingston regions (MP 24-93), although the majority were taken upstream of Bowline Point (MP 37.5) between MP 39 and 46 (TI 1976e: p. V-94; McFadden 1977:p. 6.56).

Sturgeon are predominately bottom dwellers during all life stages. The eggs are demersal and strongly adhesive, and are deposited in large masses on the river bottom (Vladykov and Greeley 1963:p. 51). Young and adults are highly adapted for preying on bottom organisms such as gastropods and benthic crustaceans (McFadden 1977:p 5.36). Temperature requirements for Atlantic and shortnose sturgeon are not available. However, since the thermal plume at the Bowline Point plant is primarily a surface phenomenon, it should have little or no effect on any sturgeon life stages that may occur in the area.

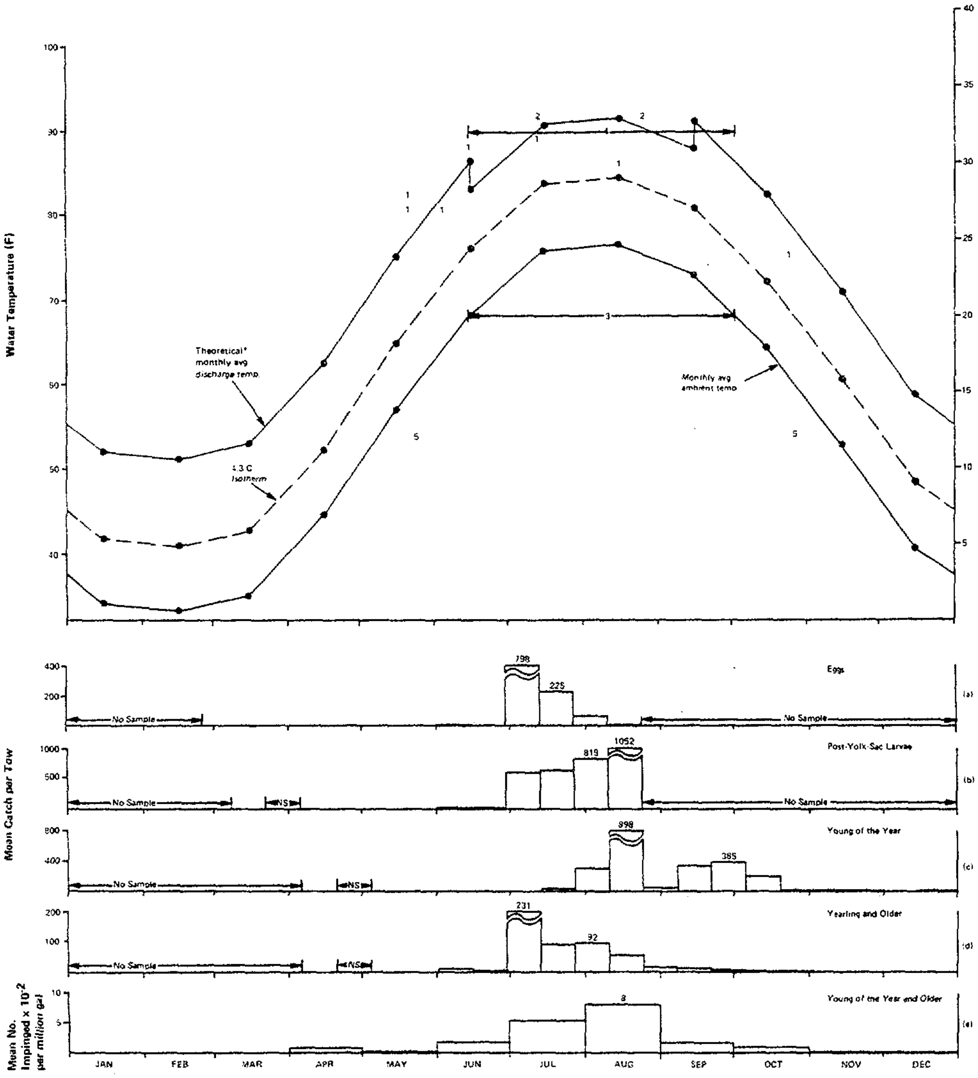
5.3.4.8 Bay Anchovy

The bay anchovy (*Anchoa mitchelli*) is a small, euryhaline, schooling fish that occurs in estuaries and coastal waters of North America from Maine to Yucatan, Mexico (Mansueti and Hardy 1967:p. 86). Bay anchovies are an important food item for many larger predator fish, and have been found to be a major food of the striped bass in the Chesapeake Bay (Raney 1952:pp. 53-55).

Bay anchovy spawn throughout the summer in coastal harbors, bays, and estuaries (Dovel 1971:p. 8; and Perlmutter 1939). In the Hudson River estuary, bay anchovy spawn predominantly in the higher salinity waters downstream of the Bowline Point plant (TI 1976e:p. V-110). The abundance of bay anchovy eggs at Bowline Point is largely determined by the intrusion of the salt front (ORU 1977:p. 9.1-66). Eggs often occur in the vicinity of Bowline Point (MP 37.5) during July (Figure 5.3-9); however, during 1973 ichthyoplankton surveys in the Hudson River, no bay anchovy eggs were collected above MP 33 (TI 1976e: p. V-111).

Bay anchovy eggs are susceptible to plume entrainment when present in the area of the Bowline Point plant. The eggs are buoyant when newly spawned, becoming demersal with advancing development (EA 1978a:p. 10-1), and have been collected throughout the water column (TI 1976e:p. V-110). No thermal tolerance information on bay anchovy eggs is available; however, since the eggs naturally occur in waters at maximum summer ambient temperatures as high as 27.3 C (TI 1976e:p. V-110), it is likely that they would also be able to tolerate most plume entrainment exposures.

After hatch, bay anchovy larvae move upstream into lower salinity nursery areas (TI 1976e:p. V-113), and are found in abundance in the vicinity of Bow-



*Assumes continual plant operation at maximum capacity.

Key to Thermal Effects Data Points

1. 24.0-32.0 C, upper avoidance temp., Meldrim, Gift, and Petrosky 1974.
2. 33.0 C, upper incipient lethal temp. (93-hr TL50) for sub-adults; EA 1978b.
3. From 20.0 C to maximum summer ambient, normal spawning temps.; Dovel 1971, TI 1976a.
4. 32.0 C, minimum estimate of optimum temp. for early development, from hatch through feeding stage (7 days); Houde 1974.
5. 12.0 C, lower incipient lethal temp. (168-hr LD60 + 2 C.; Wyllie et al. 1976.

Key to Seasonal Distribution Histograms

(a) Mean no. eggs collected in 5-min plankton tows for 1974-1975, RM 37; TI 1975a, TI 1976a.
(b) Mean no. post-yolk-sac larvae collected in 5-min plankton tows for 1974-1975, RM 37; TI 1975a, TI 1976a.
(c) Mean no. young of the year collected in 5-min bottom trawls for 1974-1975, RM 36-37; TI 1976b, TI 1976c.
(d) Mean no. yearling and older collected in 5-min bottom trawls for 1974-1975, RM 36-37; TI 1976b, TI 1976c.
(e) Mean no. young of the year and older from impingement collections for 1973-1976; Orange and Rockland 1977.

Figure 5.3-9. Thermal effects diagram for bay anchovy at the Bowline Point Generating Station on the Hudson River.

line Point during summer months (Figure 5.3-9). Bay anchovy larvae occur throughout the water column (ORU 1977:p. 9.1-71) and, therefore, would be susceptible to exposure to all portions of the thermal plume.

Although actual thermal tolerance limits have not been determined for bay anchovy larvae, they appear to be well adapted to high temperatures. Houde (1974:pp. 273-274, 282) successfully reared bay anchovy larvae at temperatures as high as 32.0 C, and observed the highest growth rate at that temperature. This optimum temperature for early development of bay anchovy exceeds river ambient temperatures (Figure 5.3-9, line number 4) (Table 5.3-8). Plume entrainment exposures to temperatures in excess of the 32 C growth optimum would last only a few seconds. Since young fish of other RIS tolerated brief exposures to temperatures much higher than their optimum temperature for early development and growth, it is unlikely that mortality of bay anchovy larvae would result from entrainment into even the maximum temperature areas of the thermal plume.

Bay anchovy juveniles occur in the Bowline Point area throughout the summer and early fall months (Figure 5.3-9), migrating downstream with the onset of cool temperatures during October (TI 1976e:p. V-115). Their abundance in the vicinity of Bowline Point is largely determined by the intrusion of saltwater into the area; young bay anchovy have been observed to occur in greatest abundance at a salinity range of approximately 3-7 ppt (Dovel 1971:p. 7; TI 1976e: p. V-115). Adults are also present in the plant area during the summer (Figure 5.3-9), although they are predominately found in the regions of the estuary located farther downstream (TI 1976e:p. V-107). Both juveniles and adults occur throughout the water column in all major habitats (shore zone, shoal, and channel areas) (TI 1976e:pp. V-107, V-113), and, therefore, would

TABLE 5.3-8 THERMAL EFFECTS SUMMARY TABLE FOR BAY ANCHOVY

				Maximum Area of Thermal Plume(a) Exceeding Temperature Limit During Typical Years				Maximum Area of Thermal Plume(a) Exceeding Temperature Limit During Unusually Warm Years			
				Surface Area		Volume		Surface Area		Volume	
Biological Activity To Be Protected	Thermal Effects Parameter	Temp. Limit or Range (C)	Reference	Acres	Percent(b) Near-field	Acre-ft	Percent(b) Near-Field	Acres	Percent(b) Near-field	Acre-ft	Percent(b) Near-field
Maximum for Survival											
Subadults	93-hr TL50	33.0	EA 1978b	0	0	0	0	<0.7	<0.01	<2.99	<0.002
Minimum Avoidance Temperature											
Adults and juveniles	Upper avoidance temps.	24.0-32.0	Meldrim, Gift & Petrosky 1974	<0.7	<0.01	<2.99	<0.002	<3.7	<0.052	<32.10	<0.022
Maximum Temperature for Early Development											
Larvae	Minimum est. of optimum temp.	32.0	Houde 1974	<0.7	<0.01	<2.99	<0.002	<0.7	<0.01	<2.99	<0.002
Thermal Shock Tolerance											
Cold shock											
Adults	168-hr LD60 + 2 C	12.0	Wyllie et al. 1976	NA	NA	NA	NA	NA	NA	NA	NA

(a) Calculations were based on the isotherm exceeding the temperature limit during operation at maximum capacity; areas and volumes are predicted according to actual field surveys conducted when the plant operation load was 93.3-93.8 percent of capacity.

(b) Percent available volume or area based on a near-field area calculated as two tidal excursions (ebb) and flood), one upstream (1.9 miles), and one downstream (3.6 miles); surface area of this near-field area = 7,067 acres, and volume = 146,987 acre-ft.

Note: NA = not applicable.

frequently come into contact with the lower isotherm areas of the thermal plume.

Juvenile and adult bay anchovy, like earlier life stages, appear to be well adapted to warm-water environments. Gallaway and Strawn (1974:p. 95) studied the distribution of bay anchovies in a thermal discharge in Galveston Bay, Texas, and found that they preferred temperatures between 24.5 C and 32.5 C, and were occasionally collected at temperatures as high as 37.0 C. The thermal tolerance limit for bay anchovy subadults acclimated to 24.0 C is 33.0 C (93-hour TL50) (EA 1978b:p. 6.2-29) (Figure 5.3-9, data points number 2). This exceeds the maximum discharge temperature at the Bowline Point plant (Table 5.3-8). Temperatures that would be potentially avoided by bay anchovy, based on avoidance temperatures reported by Meldrim et al. (1974:p. 41), normally occur only within the immediate vicinity of the discharge where velocities are too high to permit residence (Figure 5.3-9, data points number 1). Therefore, bay anchovy juveniles and adults that encounter the area influenced by the thermal discharge from the Bowline Point plant would not be excluded from any major habitat because of the elevated temperatures.

Bay anchovies that become acclimated to the warmer waters of the thermal plume could be subjected to a sudden decrease in temperature in the event of a plant shutdown. The lower incipient lethal temperature for bay anchovy acclimated to 20.0 C is 12.0 C (168-hour LD60 + 2 C) (Wyllie et al. 1976:p. 17). Thus, during the summer and fall months the potential for cold shock is minimal since bay anchovy can tolerate large temperature drops (at least 8.0 C). During the winter months when a greater cold shock potential may exist, bay anchovy are no longer found in the Bowline Point vicinity (Figure 5.3-9, having migrated downstream to coastal waters.

In summary:

1. Bay anchovy commonly occur in the vicinity of Bowline Point during summer and early fall months; their abundance in the area of the plant is largely determined by the upstream intrusion of the salt front.
2. Since the distribution of bay anchovy in the brackish waters of the estuary is not restricted to any unique habitat, all life stages would be potentially susceptible to thermal plume exposures.
3. Although thermal tolerance information on the early life stages of bay anchovy is not available, this species appears to be well adapted to warm-water environments; mortality resulting from plume exposures is not likely to occur.
4. The optimum temperature for development and growth of bay anchovy larvae is much higher than normal river temperatures, and no detrimental effects on growth of young bay anchovy because of the warm plume temperatures would occur.
5. Based on thermal tolerance limits and avoidance temperatures, bay anchovy juveniles and adults would not be excluded from any major habitat within the thermal plume because of elevated temperatures.
6. The potential for cold shock in the event of a plant shutdown is minimal since bay anchovy are not found in the plant vicinity during the winter months.

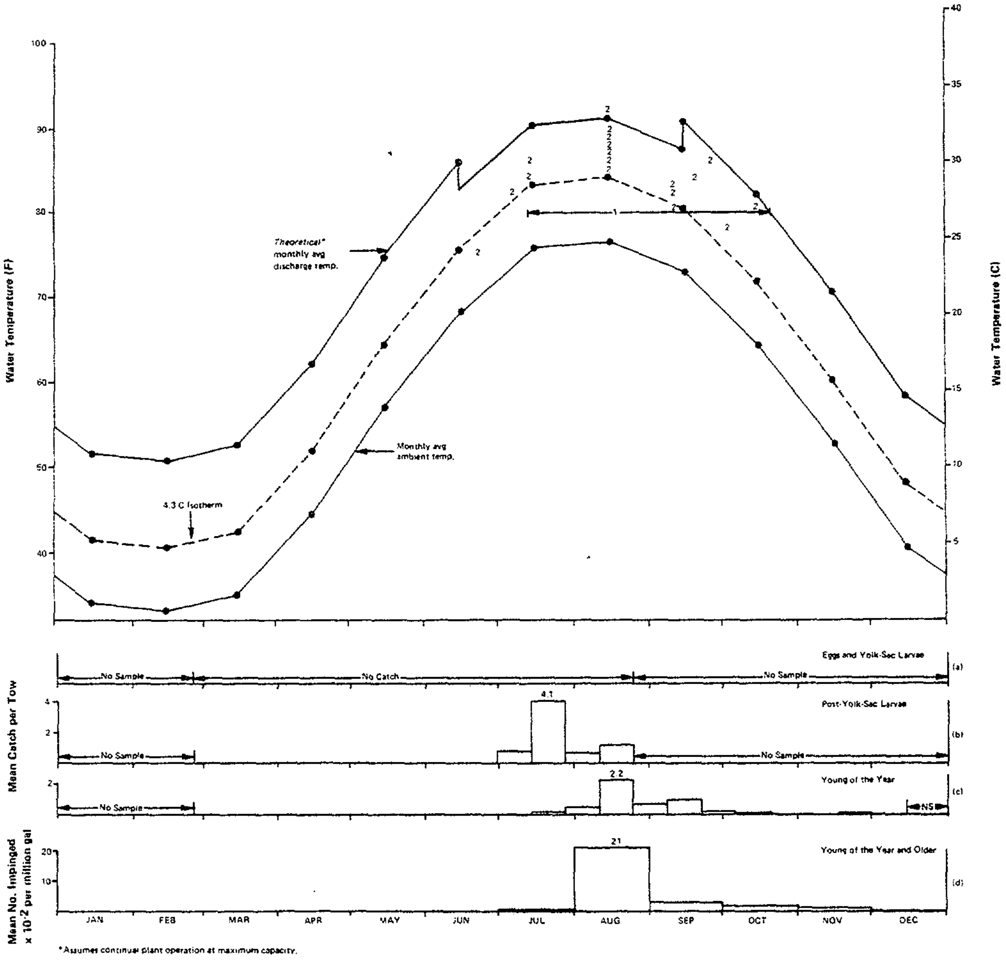
5.3.4.9 Weakfish

The weakfish (Cynoscion regalis) is a marine species occurring along the Atlantic coast of the United States from Massachusetts Bay to eastern Florida, and is an important sport and commercial species in the middle Atlantic area, including New York coastal waters (Perlmutter et al. 1956:p. 1).

Weakfish utilize the Hudson River estuary primarily as a nursery area. Young weakfish move upstream from coastal spawning areas near the mouth of the estuary into the brackish portion of the lower regions of the Hudson River, where they remain during the warmer summer and fall months (TI 1976e:p. V-169). Post-yolk-sac larvae and young-of-the-year weakfish occur in the vicinity of Bowline Point predominately during July and August, although they are not abundant (Figure 5.3-10). Eggs, yolk-sac larvae, and adults are not found in the Hudson River as far upstream as Bowline Point (TI 1976e:p. V-169).

The susceptibility of young weakfish to thermal plume exposures is greatly reduced because of their preference for the deeper channel areas of the estuary (TI 1976e:pp. V-270 - V-274). Although no published thermal tolerance data are available, weakfish have been shown to avoid temperatures ranging from 3.0 to 7.0 C above ambient river temperatures (Figure 5.3-10, data points number 2) (Public Service Electric and Gas Company, Newark, New Jersey, personal communication). Thermal plume temperatures exceeding the minimum avoidance temperature reported would be found within a maximum area less than 3.7 acres and volume less than 32.1 acre-ft (Table 5.3-9). Avoidance temperatures typically occur within the thermal plume only in the immediate vicinity of the discharge where velocities do not permit extended residence. Therefore, weakfish that may come into contact with the elevated temperatures produced by the thermal discharge would not be excluded from large areas because of the elevated temperatures.

The optimum temperature for growth and performance of juvenile weakfish, as approximated by the final preferendum, is 26.7 C (Wyllie et al. 1976:p. 15). This temperature is exceeded in areas of the thermal plume greater than 2.0 C above ambient--up to 141 acres and 604 acre-ft (Figure 5.3-10, line number 2)



*Assumes continual plant operation at maximum capacity.

Key to Thermal Effects Data Points

1. 26.7 C, final preferendum for juveniles: Wyllie et al, 1976.
2. 24.0-33.0 C, upper avoidance temp. for juveniles; Public Service Electric and Gas Company, personal communication.

Key to Seasonal Distribution Histograms

(a) Mean no. eggs and yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 37, TI 1975a, TI 1976a, TI 1977.

(b) Mean no. post-yolk-sac larvae collected in 5-min plankton tows for *1974-1976, RM 37; TI 1975a, TI 1976a, TI 1977.*

(c) Mean no. young of the year collected in 5-min plankton tows for 1974-1976, RM 36-37; TI 1975a, TI 1976a, TI 1977.

(d) Mean no. young of the year and older from impingement collections for 1973-1976, Orange and Rockland 1977.

Figure 5.3-10. Thermal effects diagram for weakfish at the Bowline Point Generating Station on the Hudson River.

TABLE 5.3-9 THERMAL EFFECTS SUMMARY TABLE FOR WEAKFISH

				Maximum Area of Thermal Plume(a) Exceeding Temperature Limit During Typical Years				Maximum Area of Thermal Plume(a) Exceeding Temperature Limit During Unusually Warm Years			
				Surface Area		Volume		Surface Area		Volume	
Biological Activity To Be Protected	Thermal Effects Parameter	Temp. Limit or Range (C)	Reference	Acres	Percent(b) Near-field	Acre-ft	Percent(b) Near-Field	Acres	Percent(b) Near-field	Acre-ft	Percent(b) Near-field
Minimum Avoidance											
Juveniles	Upper avoidance temp.	24.0-33.0	Public Service Electric and Gas Co.	<3.7	<0.052	<32.10	<0.022	<3.7	<0.052	<32.10	<0.022
Optimum for Performance and Growth											
Juveniles	Final preferendum	26.7	Wyllie et al. 1976	<141.0	<1.995	<604.0	<0.41	>141.0	>1.995	>604.0	>0.41

(a) Calculations were based on the isotherm exceeding the temperature limit during operation at maximum capacity; areas and volumes are predicted according to actual field surveys conducted when the plant operation load was 93.3-93.8 percent of capacity.

(b) Percent available volume or area based on a near-field area calculated as two tidal excursions (ebb) and flood), one upstream (1.9 miles), and one downstream (3.6 miles); surface area of this near-field area = 7,067 acres, and volume = 146,987 acre-ft.

Note: NA = not applicable.

(Table 5.3-9). However, since the final preferendum only estimates some point within the optimum temperature range, satisfactory growth and performance may occur within a portion of that area. However, because of the preference of young weakfish for the deeper channel areas of the estuary, and the predominately surface-oriented nature of the thermal plume, the potential for contact with the elevated temperature plume waters is minimal.

In summary:

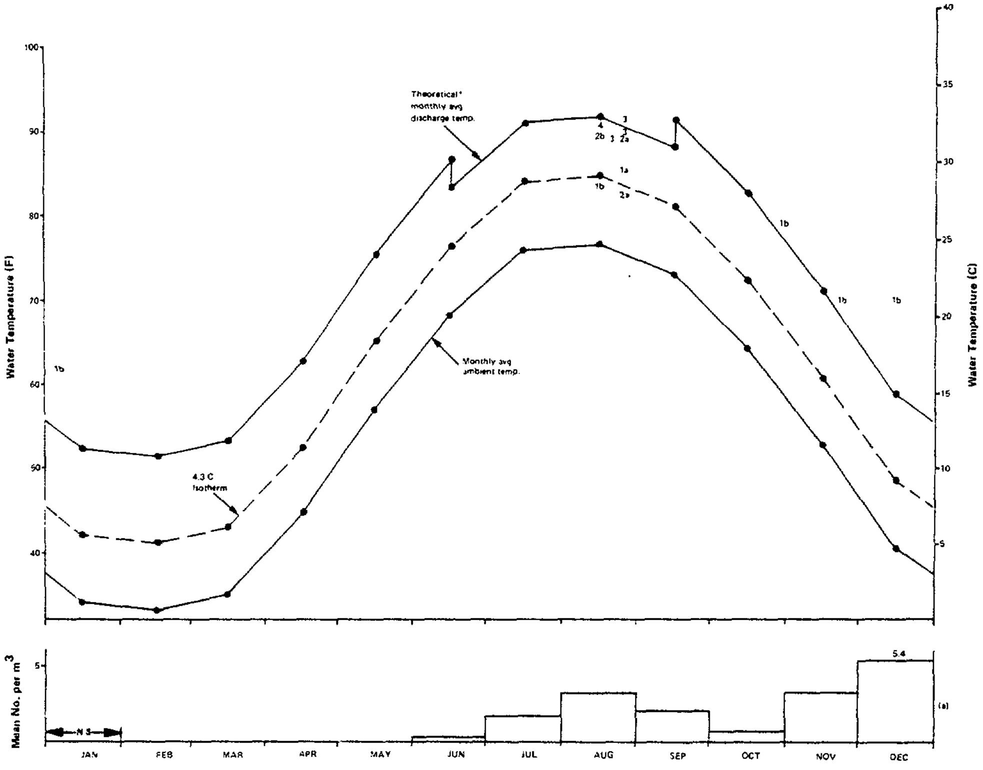
1. The susceptibility of weakfish to thermal plume exposures is limited to summer and early fall months when the young are present in the vicinity of Bowline Point.
2. The probability of exposure to the thermal plume is decreased considerably because of their preference for the deeper channel areas of the estuary.
3. Based on upper avoidance temperatures and the optimum temperature for growth and performance, weakfish that may be present within the area influenced by the thermal discharge would not be adversely affected by the elevated plume temperatures.

5.3.4.10 Neomysis

Neomysis americana is the most common mysid inhabiting the northeastern estuaries and inshore coastal waters of the United States (Hopkins 1958:p. 5) and is very abundant in the lower Hudson River estuary (NYU 1974:pp. 122-141).

Neomysis are important because of their role as a major food item for many fish species, including young striped bass (McFadden 1977:pp. 4.8, 5.9).

Neomysis have been collected in the Bowline Point area from June through December (Figure 5.3-11). The upstream penetration of Neomysis into the Hudson



*Assumes continual plant operation at maximum capacity.

Key to Thermal Effects Data Points

1. 17.0-29.4 C, 24-hr TL50s; (a) EA 1978b, (b) Mihursky and Kennedy 1967.
2. 28.8-31.7 C, 30-min TL95s; (a) EA 1978b, (b) NYU 1973.
3. 31.7-33.0 C, 10-min TL95s; EA 1978b.
4. 32.5 C, 5-min TL95; NYU 1973.

Key to Seasonal Distribution Histograms

(a) Mean no. per m^3 collected in 10-min plankton tows at night for 1974-1976, RM 36-40; Orange and Rockland 1977.

Figure 5.3-11. Thermal effects diagram for *Neomysis americana* at the Bowline Point Generating Station on the Hudson River.

River estuary is dependent upon the intrusion of the salt front; therefore, only when saline water is present at Bowline Point would Neomysis be exposed to the elevated plume temperatures produced by the Bowline Point plant (ORU 1977:pp. 8.1-69 - 8.1-71).

When present in the vicinity of Bowline Point, Neomysis could be subjected to short-term exposures to elevated temperatures as a result of plume entrainment. Safe temperatures (TL95s) for Neomysis range from 28.8 to 33.0 C for exposure durations of 5, 10, and 30 minutes when acclimated to normal river temperatures during the summer (EA 1978b:Table 5.2-11; NYU 1973:pp. 136-139) (Table 5.3-10). Exposure to plume temperatures greater than these safe temperatures would occur only for organisms entrained directly into the warmest portions of the discharge, where exposures to the higher elevated temperatures would last only 5-10 seconds (Figure 5.3-11, data points number 2, 3, and 4). No information on the thermal tolerance of Neomysis for exposures less than 5 minutes is available; however, Crangon septemspinosa, a species with thermal tolerance limits similar to those reported for Neomysis (EA 1978a:p. 12-13; 1978b:Table 5.2-11), tolerated a 10-second exposure to temperatures over 5.0 C higher than thermal tolerance limits for a 10-minute exposure. Since the 10-minute TL95s for Neomysis are within 1.2 C of the maximum discharge temperatures, a 10-second tolerance limit similar to that reported for Crangon would assure survival of Neomysis that are entrained into even the warmest discharge waters.

An important factor that minimizes the exposure of Neomysis to entrainment within higher elevated temperatures of the thermal plume is the diurnal behavior pattern of this species. Neomysis are primarily distributed in the bottom water strata during the day (Herman 1963:p. 231), and migrate toward

TABLE 5.3-10 THERMAL EFFECTS SUMMARY TABLE FOR NEOMYSIS AMERICANA

				Maximum Area of Thermal Plume[a] Exceeding Temperature Limit During Typical Years				Maximum Area of Thermal Plume[a] Exceeding Temperature Limit During Unusually Warm Years			
				Surface Area		Volume		Surface Area		Volume	
Biological Activity To Be Protected	Thermal Effects Parameter	Temp. Limit or Range (C)	Reference	Acres	Percent[b] Near-field	Acre-ft	Percent[b] Near-Field	Acres	Percent[b] Near-field	Acre-ft	Percent[b] Near-field
Maximum for Survival											
Adults	24-hr TL50	17.0-29.4	EA 1978; Mihursky & Kennedy 1967	<0.7	<0.01	<2.99	<0.002	<10.1	<0.143	<113.0	<0.077
Thermal Shock Tolerance											
Entrainment Shock											
Adults	30-min TL95	28.8-31.7	EA 1978b; NYU 1973	NA	NA	NA	NA	NA	NA	NA	NA
Adults	10-min TL95	31.7-33.0	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Adults	5-min TL95	32.5	NYU 1973	NA	NA	NA	NA	NA	NA	NA	NA

(a) Calculations were based on the isotherm exceeding the temperature limit during operation at maximum capacity; areas and volumes are predicted according to actual field surveys conducted when the plant operation load was 93.3-93.8 percent of capacity.

(b) Percent available volume or area based on a near-field area calculated as two tidal excursions (ebb) and flood), one upstream (1.9 miles), and one downstream (3.6 miles); surface area of this near-field area = 7,067 acres, and volume = 146,987 acre-ft.

Note: NA = not applicable.

the surface at night (Herman 1963:p. 231; Ginn 1977:pp. 103-105). Since discharge temperatures are generally reduced at night owing to off-peak load conditions, Neomysis that become entrained into the thermal plume during nightly vertical migrations would be exposed to lower discharge temperatures than observed during peak operation.

Although exposures to the higher plume temperatures are limited to only 5-10 seconds, organisms may be exposed to the lower plume isotherms for somewhat longer time periods. Twenty-four-hour TL50s range from 17.0 to 29.4 C (EA 1978b:Table 6.2-8; Mihursky and Kennedy 1967:p. 27), depending on the time of the year and thus the acclimation temperature. These tolerance limits range from 4.0 to 15.0 C above ambient. Areas of the plume warmer than these tolerance limits usually occur only in the immediate vicinity of the discharge where high velocities do not permit extended exposure (Figure 5.3-11, data points 1a and 1b) (Table 5.3-10).

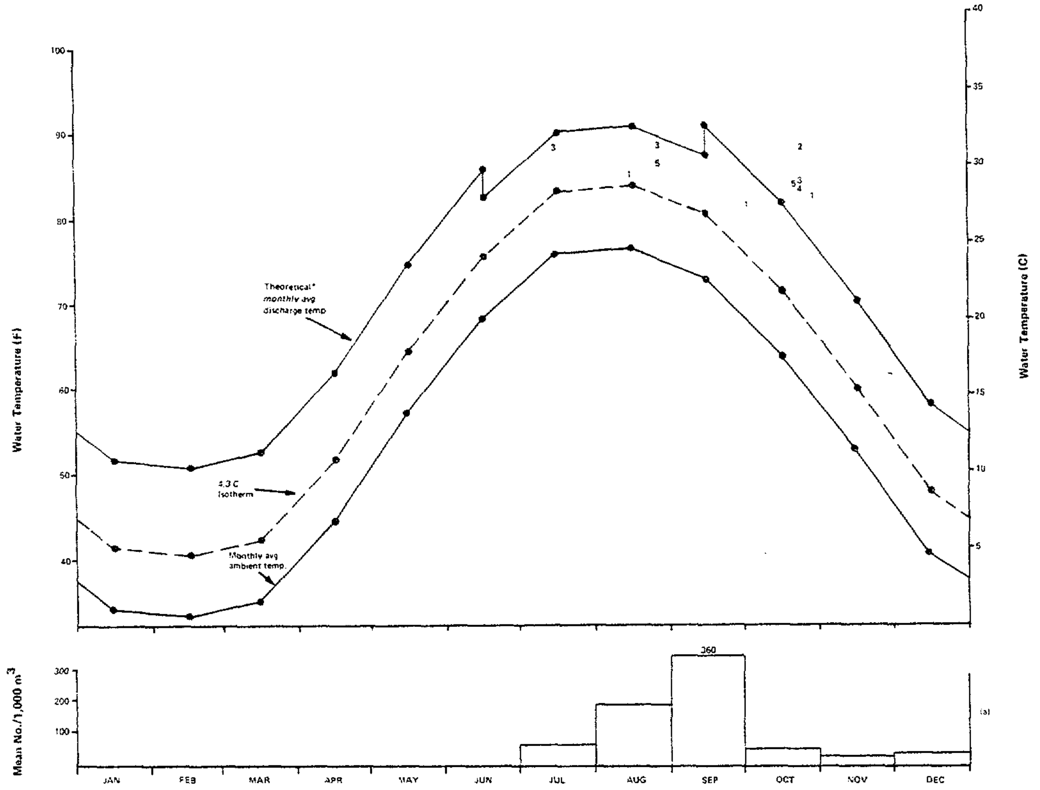
In summary:

1. The susceptibility of Neomysis to thermal plume exposures is limited to those times of the year when saline water is present in the vicinity of Bowline Point.
2. Neomysis that become entrained into the thermal plume during nightly vertical migrations towards the water surface would normally be exposed to lower discharge temperatures as a result of off-peak load conditions during the night.
3. Based on the tolerance of Neomysis to elevated temperatures for both short-term and extended exposures, mortality is not predicted to occur due to entrainment into the thermal plume created by the Bowline Point plant.

5.3.4.11 Crangon

Crangon septemspinosa (sand shrimp) is a common inhabitant of estuaries and near-shore coastal waters and has been collected along the northwestern Atlantic from Newfoundland to eastern Florida (Price 1962:p. 144; Williams 1965: p. 89). Both larval and mature Crangon are common in the lower Hudson River estuary, but are not abundant (Hopkins, unpublished:p. 19).

Crangon have been collected in the Bowline Point vicinity from July through December (Figure 5.3-12). Like Neomysis, Crangon's upstream penetration into the Hudson River is dependent on the intrusion of the salt front (Hopkins, unpublished:p. 19). Therefore, Crangon would be exposed to the elevated plume temperatures only when saline water is present in the area of the plant. Early larval stages of Crangon are planktonic (Sandifer 1972:p. 284) and, therefore, would be susceptible to plume entrainment exposures when in the vicinity of Bowline Point. Older larval stages and adults are predominately epibenthic (Price 1962:pp. 249-250; Sandifer 1972:p. 284) and would be less susceptible to plume entrainment. Safe temperatures (TL95s) for Crangon acclimated to 16.0-24.0 C range from 28.6 to 31.8 C for continuous exposures of 10, 30, and 60 minutes (EA 1978b:Table 5.2-11). Exposures to plume temperatures greater than these safe levels would occur only for Crangon entrained directly into the warmest portions of the discharge, where exposures to the higher isotherms would last only 5-10 seconds (Figure 5.3-12, data points number 3, 4, and 5). Crangon acclimated to 16.0 C have been shown to tolerate temperatures as high as 33.9 C (TL95) for a 10-second exposure (17.9 C above ambient) (EA 1978b:Table 5.2-11). This tolerance limit exceeds maximum discharge temperatures throughout the year (Figure 5.3-12, data points number 6).



*Assumes continual plant operation at maximum capacity

Key to Thermal Effects Data Points

1. 27.5-29.5 C, 24-hr TL50s; Mihursky and Kennedy 1967.
2. 33.9 C, 10-sec TL95; EA 1978b.
3. 29.0-31.8 C, 30-min TL95s; EA 1978b.
4. 28.6 C, 60-min TL95; EA 1978b.
5. 28.7-30.3C, 10-min TL95s; EA 1978b.

Key to Seasonal Distribution Histograms

(a) Mean no. per 1,000 m^3 collected in 10-min bottom trawls at night for 1973-1975, RM 37-42; Orange and Rockland 1977.

Figure 5.3-12. Thermal effects diagram for *Crangon septemspinosa* at the Bowline Point Generating Station on the Hudson River.

Therefore, mortality of Crangon would not be expected as a result of entrainment into even the warmest portions of the thermal plume.

Although exposures to the higher plume temperatures are limited to only 5-10 seconds, Crangon inhabiting the bottom area near the discharge would intermittently be exposed to the lower isotherms of the thermal plume for longer periods, depending on the tide. Twenty-four-hour TL50s range from 27.5 to 29.5 C, these temperatures being from 4.5 to 13.0 C above ambient (Figure 5.3-12, data points number 1) (Milhursky and Kennedy 1967:p. 27). Plume temperatures greater than these tolerance levels would not impact the bottom areas, and would occur only in the high velocities adjacent to the diffuser ports (Table 5.3-11).

In summary:

1. The susceptibility of Crangon to thermal plume exposures is limited to those times of the year when saline water is present in the vicinity of Bowline Point.
2. The potential for entrainment of older larvae and adults into the warmer portions of the thermal plume is reduced because of their predominately epibenthic existence.
3. Based on the tolerance of Crangon to elevated temperatures for both short-term and extended exposures, mortality is not predicted to occur due to entrainment into the thermal plume created by the Bowline Point plant.

5.3.4.12 Gammarus spp.

Three species of gammarid amphipods found along the Atlantic coast of North America have been reported to inhabit the Hudson River estuary: Gammarus

TABLE 5.3-11 THERMAL EFFECTS SUMMARY TABLE FOR CRANGON SEPTEMSPINOSA

				Maximum Area of Thermal Plume(a) Exceeding Temperature Limit During Typical Years				Maximum Area of Thermal Plume(a) Exceeding Temperature Limit During Unusually Warm Years			
				Surface Area		Volume		Surface Area		Volume	
Biological Activity To Be Protected	Thermal Effects Parameter	Temp. Limit or Range (C)	Reference	Acres	Percent(b) Near-field	Acre-ft	Percent(b) Near-Field	Acres	Percent(b) Near-field	Acre-ft	Percent(b) Near-field
Maximum for Survival											
Adults	24-hr TL50	27.5-29.5	Mihursky & Kennedy 1967	<0.7	<0.01	<2.99	<0.002	<10.1	<0.143	<113.0	<0.077
Thermal Shock Tolerance											
Adults	10-min TL95	28.7-30.3	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Adults	30-min TL95	29.0-31.8	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Adults	60-min TL95	28.6	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Adults	10-second TL95	33.9	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA

(a) Calculations were based on the isotherm exceeding the temperature limit during operation at maximum capacity; areas and volumes are predicted according to actual field surveys conducted when the plant operation load was 93.3-93.8 percent of capacity.

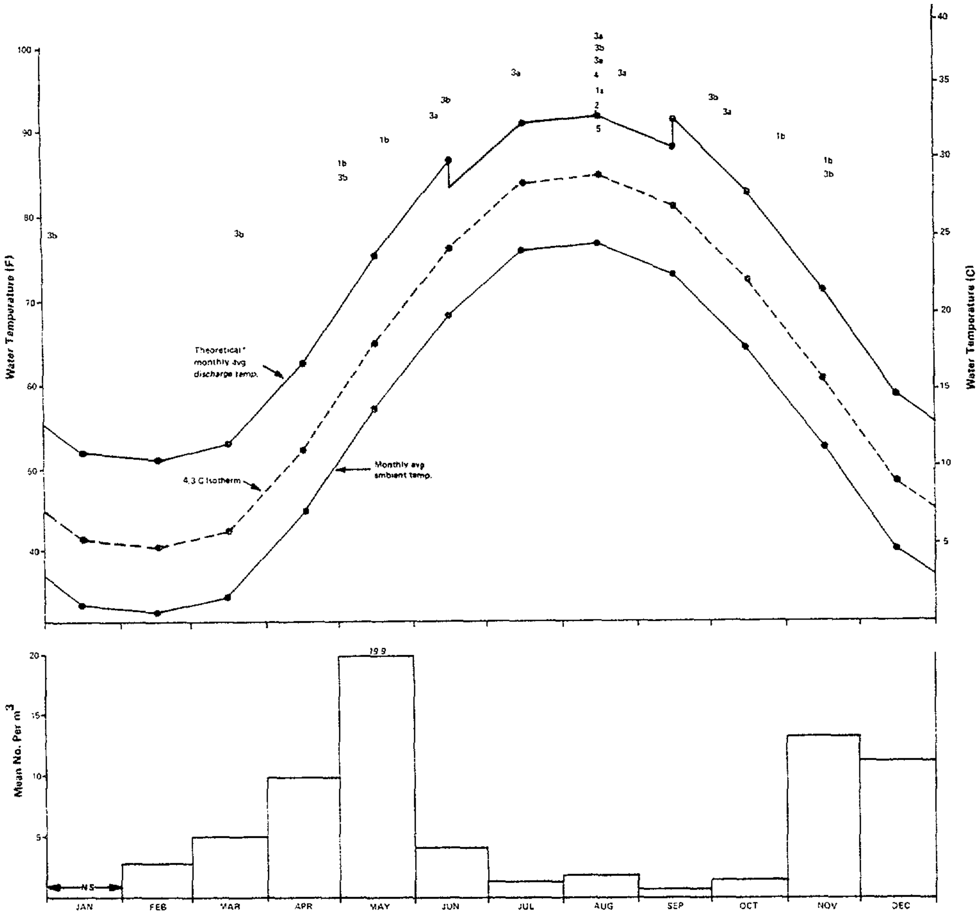
(b) Percent available volume or area based on a near-field area calculated as two tidal excursions (ebb) and flood), one upstream (1.9 miles), and one downstream (3.6 miles); surface area of this near-field area = 7,067 acres, and volume = 146,987 acre-ft.

Note: NA = not applicable.

fasciatus, G. tigrinus, and G. daiberi (Ginn 1977:p. 3; Ristich et al. 1977: p. 260). G. fasciatus is a freshwater species found in coastal drainages from Cape Cod and southern New England south to tributaries of the Chesapeake Bay, in lakes and rivers of the St. Lawrence River system (Bousfield 1958:p. 69; 1973:p. 53), and in the Great Lakes (Clemens 1950:p. 42). G. daiberi occurs in salinities up to 15 ppt and ranges from the Hudson River to South Carolina (Bousfield 1973:p. 52). G. tigrinus ranges from southern Labrador south to Chesapeake Bay, although it is found intermittently in coastal areas as far south as Florida (Bousfield 1973:p. 51). Gammarus spp. are a major food item for many Hudson River fishes (McFadden 1977:p. 48; ORU 1977:p. 8.1-169).

The most abundant amphipod in the Hudson River is G. daiberi (Ginn 1977:p. 68), which is predominantly pelagic during the night and benthic during the day (ORU 1977:p. 8.1-163). G. tigrinus was the least abundant amphipod collected in the Hudson River by Ginn (1977:pp. 66-68), and is essentially benthic (Bousfield 1973:p. 51). G. fasciatus is benthic and semipelagic (Bousfield 1973:p. 53), and is generally confined to the upriver portions of the Hudson River estuary (Ginn 1977:p. 68). Although the potential exists for exposure of all three species to the thermal plume created by the Bowline Point plant, only G. daiberi has been identified in near-field plankton collections (ORU 1977:pp. 8.1-162).

Gammarus spp. are present in the area of Bowline Point throughout the year (Figure 5.3-13), but are most susceptible to plume entrainment during periods of peak abundance in the spring and late fall. Thirty-minute safe temperatures (TL95s) for Gammarus spp. range from 25.5 to 37.1 C, depending on acclimation (ambient) temperature (EA 1978b:Table 5.2-11; NYU 1973:pp. 130-132). These safe temperatures are several degrees centigrade higher than maximum



*Assumes continual plant operation at maximum capacity.

Key to Thermal Effects Data Points

1. 30.5-33.8 C, 24-hr TL50s; (a) EA 1978b, (b) Mihursky and Kennedy 1967.
2. 33.0 C, 48-hr TL50; NYU 1973.
3. 25.5-37.1 C, 30-min TL95s; (a) EA 1978b, (b) NYU 1973.
4. 34.3 C, maximum tolerable temp. of eggs and young for 60-minute exposure; Ginn 1977.
5. 31.7 C, avoidance temp., Ginn 1977.

Key to Seasonal Distribution Histograms

(a) Mean no. per m^3 collected in 10-min plankton tows at night for 1974-1976, RM 36-40; Orange and Rockland 1977.

Figure 5.3-13. Thermal effects diagram for *Gammarus* spp. at the Bowline Point Generating Station on the Hudson River.

discharge temperatures throughout the year (Figure 5.3-13, data points number 3a and 3b). In addition, Gammarus spp. acclimated to 19.0-22.0 C tolerated temperatures as high as 40.7-42.2 C (TL95s) for 10-second exposures (EA 1978b: Table 5.2-11). Therefore, no mortality of Gammarus spp. would occur as a result of plume entrainment.

Although exposures to the higher plume temperatures are limited to only 5-10 seconds, Gammarus spp. may be exposed to the lower plume isotherms for longer time periods. Twenty-four-hour TL50s for Gammarus spp. range from 30.5 to 33.8 C, depending on acclimation (ambient) temperature (EA 1978b:Table 5.2-11; Mihursky and Kennedy 1967:p. 27; NYU 1973:pp. 132-133). These tolerance limits also exceed maximum discharge temperatures during all times of the year (Figure 5.3-13, data points number 1a and 1b). Gammarus spp. acclimated to high river ambients (25.0 C) tolerated a temperature increase of 8.0 C above ambient for 48 hours (TL50 = 33.0 C) (Figure 5.3-13, data point number 2); temperatures greater than this tolerance limit would occur only in areas of the discharge where high velocities would prevent extended exposures (Table 5.3-12). Furthermore, the upper avoidance temperature for Gammarus spp., 31.7 C (Ginn 1977:p. 159), would similarly occur only within the immediate vicinity of the discharge (Table 5.3-12) (Figure 5.3-13, data points number 5). Therefore, the distribution and abundance of Gammarus spp. within the area influenced by the thermal plume from the Bowline Point plant should not be altered as a result of the elevated temperatures.

Reproduction of Gammarus spp. has also been shown to be unaffected by exposures to elevated temperatures comparable to those that would be encountered in the thermal plume of the Bowline Point plant. Ginn (1977:pp. 136-140) reported that the reproductive activities of mature Gammarus spp. were not af-

TABLE 5.3-12 THERMAL EFFECTS SUMMARY TABLE FOR GAMMARUS SPP.

				Maximum Area of Thermal Plume[a] Exceeding Temperature Limit During Typical Years				Maximum Area of Thermal Plume[a] Exceeding Temperature Limit During Unusually Warm Years			
				Surface Area		Volume		Surface Area		Volume	
Biological Activity To Be Protected	Thermal Effects Parameter	Temp. Limit or Range (C)	Reference	Acres	Percent[b] Near-field	Acre-ft	Percent[b] Near-Field	Acres	Percent[b] Near-field	Acre-ft	Percent[b] Near-field
Maximum for Survival											
Adults	24-hr and 48-hr TL50	30.5-33.8	EA 1978b; Mihursky & Kennedy 1967; NYU 1973	0	0	0	0	<0.7	<0.10	<2.99	<0.002
Minimum Avoidance											
Adults	Avoidance temp.	31.7	Ginn 1977	<0.7	<0.010	<2.99	<0.002	<0.7	<0.010	<2.99	<0.002
Thermal Shock Tolerance											
Entrainment Shock											
Eggs & young	Max. tolerable temp. for 60-min. exposure	34.3	Ginn 1977	NA	NA	NA	NA	NA	NA	NA	NA
Adults	30-min TL95	25.5-37.1	EA 1978b; NYU 1973	NA	NA	NA	NA	NA	NA	NA	NA
Adults	10-min TL95[c]	34.2-37.5	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA
Adults	10-sec TL95[c]	40.7-42.5	EA 1978b	NA	NA	NA	NA	NA	NA	NA	NA

(a) Calculations were based on the isotherm exceeding the temperature limit during operation at maximum capacity; areas and volumes are predicted according to actual field surveys conducted when the plant operation load was 93.3-93.8 percent of capacity.

(b) Percent available volume or area based on a near-field area calculated as two tidal excursions (ebb) and flood), one upstream (1.9 miles), and one downstream (3.6 miles); surface area of this near-field area = 7,067 acres, and volume = 146,987 acre-ft.

(c) Data not plotted on Figure 5.3-13.

Note: NA = not applicable.

fected by up to 60-minute exposures to an 8.3 C temperature shock above an ambient temperature of 26.0 C. In addition, the same exposure did not affect the release of young by ovigerous female Gammarus spp. (Figure 5.3-13, data point number 4). Ginn (1977:pp. 139-143) further reported that a 17-day exposure of Gammarus spp. to a 15.6 C elevation above ambient (10 C) actually stimulated reproductive activities. Since these safe temperature increases reported by Ginn exceed potential thermal plume exposures, no detrimental effects on the reproduction of Gammarus spp. would occur because of exposure to elevated temperatures within the Bowline Point plant's thermal plume.

In summary:

1. Gammarus spp. are susceptible to thermal plume exposures throughout the year, although the abundance of Gammarus spp. in the Bowline Point vicinity is relatively low during summer months.
2. Gammarus spp. are extremely tolerant of short-term exposures to elevated temperatures, and no mortality would occur as a result of entrainment into the thermal plume created by the Bowline Point plant.
3. Based on the tolerance of Gammarus spp. to extended exposures, their avoidance responses to high temperatures, and their temperature requirements for reproduction, the distribution and abundance of Gammarus spp. within the area influenced by the thermal plume would not be affected by the elevated temperatures.

REFERENCES: CHAPTER 5

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. Fish Wildl. Serv., Fish. Bull. 74, Vol. 53. 577 pp.

Bousfield, E. L. 1973. Shallow-water Gammaridean Amphipoda of New England. Cornell University Press, Ithaca, New York. 312 pp.

Bousfield, E. L. 1958. Fresh-water amphipod crustaceans of glaciated North America. Can. Field Nat. 72(2):55-113.

Boyle, R. H. 1969. The Hudson River, a Natural and Unnatural History. W. W. Norton and Co. Inc., New York. 304 pp.

Breder, C. M., Jr. and D. E. Rosen. 1966. Modes of Reproduction in Fishes. T. F. H. Publications, Jersey City, N.J.

Brett, J. R. 1971. Energetic responses of salmon to temperature. A study of some thermal relations in the physiology and fresh water ecology of sockeye salmon (Oncorhynchus nerka). Am. Zool. 11(1):99-113.

Carlander, K. D. (Ed.). 1969. Handbook of Freshwater Fishery Biology. Life history data on freshwater fishes of the United States and Canada, exclusive of the Perciformes. Volume I. Iowa State Univ. Press, Ames, Iowa. 752 pp.

Clemens, H. P. 1950. Life cycle and ecology of Gammarus fasciatus. Franz Theodore Stone Inst. Hydrobiol. Ohio State Univ. Contrib. No. 12. 63 pp.

Coutant, C. C. 1975. Temperature selection by fish--a factor in power plant impact assessments. Pages 575-597 In Environmental Effects of Cooling Systems at Nuclear Power Stations, Proceedings of a Symposium, Oslo, 26-30 August 1974. IAEA-SM-187/11. Vienna.

Dadswell, M. J. 1975. Biology of the shortnose sturgeon (Acipenser brevirostrum) in the St. John River Estuary, New Brunswick, Canada. Huntsman Marine Laboratory, St. Andrews, Can.

Dovel, W. L. 1971. Fish eggs and larvae of the Upper Chesapeake Bay. NRI Special Report No. 4.

Ecological Analysts, Inc. (EA). 1978a. Thermal effects literature review for Hudson River representative species. Prepared for Central Hudson Gas & Electric Corporation, Consolidated Edison Company of New York, Inc., Orange and Rockland Utilities, Inc.

Ecolgical Analysts, Inc. (EA). 1978b. Hudson River thermal effects studies for representative species. Final Report. Prepared for Central Hudson Gas & Electric Corporation, Orange and Rockland Utilities, Inc., and Consolidated Edison Company of New York, Inc.

Ecological Analysts, Inc. (EA). 1978c. Field studies of the effects of thermal discharges from Roseton and Danskammer Point Generating Stations on Hudson River fishes. Prepared for Central Hudson Gas & Electric Corporation.

Gallaway, J. and K. Strawn. 1974. Seasonal abundance and distribution of marine fishes at a hot-water discharge in Galveston Bay, Texas. Contrib. Mar. Sci. 18:71-137.

Ginn, T. C. 1977. An ecological investigation of Hudson River macrozooplankton in the vicinity of a nuclear power plant. Ph.D. Dissertation. New York University, New York.

Greeley, J. R. 1937. Fishes of the area with annotated list. In A Biological Survey of the Lower Hudson Watershed, E. Moore (Ed.). NYSCD:45-124.

Herman, S. S. 1963. Vertical migration of the opossum shrimp, Neomysis americana Smith. Limnol. Oceanogr. 8(2):228-238.

Hopkins, T. L. 1958. On the breeding and occurrence of opossum shrimp (order Mysidacea) in Indian River Inlet, Delaware. M. S. Thesis, Univ. Del. 36 pp.

Hopkins, W. E. (Unpublished). Hudson River zooplankton: seasonal distribution and relative abundance. Boyce-Thompson Institute, Yonkers, N.Y.

Houde, E. D. 1974. Effects of temperature and delayed feeding on growth and survival of larvae of three species of subtropical marine fishes. Marine Biology 26:271-285.

Howe, A. B. 1971. Biological investigation of Atlantic tomcod, Microgadus tomcod, in the Wewantic River estuary, Massachusetts. Ph.D. Dissertation, Univ. Mass. 82 pp.

Kendall, A. W., Jr. and F. J. Schwartz. 1968. Lethal temperature and salinity tolerances of the white catfish, Ictalurus catus, from the Patuxent River, Maryland. Chesapeake Sci. 9(2):103-108.

Lawler, Matusky & Skelly Engineers (LMS). 1978. Bowline Point Generating Station hydrothermal analysis. Prepared for Orange and Rockland Utilities, Inc. Pearl River, N.Y.

Mansueti, R. J. 1964. Eggs, larvae and young of the white perch, Roccus americanus, with comments on its ecology in the estuary. Chesapeake Sci. 5(1/2):3-45.

Mansueti, A. J. and J. D. Hardy, Jr. 1967. Development of Fishes of the Chesapeake Bay Region: An Atlas of Egg, Larval, and Juvenile Stages. Part 1. Nat. Resour. Inst., Univ. Md. 202 pp.

Marcy, B. C. 1976. Fishes of the lower Connecticut River and the effects of the Connecticut Yankee Plant. Pages 61-113 In The Connecticut River Ecological Study, D. Merriman and Lyle M. Thorpe (Eds.). The Impact of a Nuclear Power Plant. Monograph No. 1. American Fisheries Society.

McFadden, J. T. 1977. Influences of Indian Point Unit 2 and other steam electric generating plants on the Hudson River estuary, with emphasis on striped bass and other fish populations. Submitted to Consolidated Edison Company of New York, Inc.

Meldrim, J. W. and J. J. Gift. 1971. Temperature preference, avoidance and shock experiments with estuarine fishes. Prepared by Ichthyological Associates, Inc., Consolidated Edison Company of New York, Inc. Ithaca, N.Y.

Meldrim, J. W., J. J. Gift, and B. R. Petrosky. 1974. The effect of temperature and chemical pollutants on the behavior of several estuarine organisms. Ichthyological Associates, Inc. Ithaca, N.Y. Bulletin No. 11.

Mihursky, J. A. and V. S. Kennedy. 1967. Effects of temperature on vertebrates and invertebrates. Pages 21-34 In Effects of Thermal Pollution on Productivity and Stability of Estuarine Communities, University of Maryland. Third Annual Report Program Activities. 1 July 1966 - 30 June 1967. Progress report to University of Maryland Water Resources Research Commission. Natural Resources Institute Ref. No. 68-34.

Miller, E. E. 1966. White catfish. Pages 430-440 In Inland Fisheries Management, Calhoun, A. (Ed.). Calif. State Dept. Fish Game.

New York University Medical Center (NYU). 1973. Hudson River ecosystem studies. Effects of entrainment by the Indian Point Power Plant on Hudson River estuary biota. Progress Report for 1971 & 1972. N.Y. Univ. Medical Center, Institute of Environmental Medicine, Laboratory for Environmental Studies. Prepared for Consolidated Edison Company of New York, Inc., N.Y.

New York University Medical Center (NYU). 1974. Hudson River ecosystem studies. Effects of entrainment by the Indian Point Power Plant on Hudson River estuary biota. Progress Report for 1973. N.Y. Univ. Medical Center, Institute of Environmental Medicine, Laboratory for Environmental Studies. Prepared for Consolidated Edison Company of New York, Inc., N.Y.

New York University Medical Center (NYU). 1976. Hudson River ecosystem studies. Effects of entrainment by the Indian Point Power Plant on Hudson River estuary biota. Progress Report for 1974. N.Y. Univ. Medical Center, Institute of Environmental Medicine, Laboratory for Environmental Studies. Prepared for Consolidated Edison Company of New York, Inc., N.Y.

New York University Medical Center (NYU). 1977. Hudson River ecosystem studies. Effects of entrainment by the Indian Point Power Plant on Hudson River estuary biota. Progress Report for 1975. N.Y. Univ. Medical Center, Institute of Environmental Medicine, Laboratory for Environmental Studies. Prepared for Consolidated Edison Company of New York, Inc., N.Y.

Orange and Rockland Utilities, Inc. (ORU). 1977. Bowline Point Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota. Prepared by Ecological Analysts, Inc. and Lawler, Matusky, and Skelley Engineers, Inc., Spring Valley, N.Y.

Otto, R. G., M. A. Kitchel, and J. O. Rice. 1976. Lethal and preferred temperatures of the alewife (Alosa pseudoharengus) in Lake Michigan. Transactions of the American Fisheries Society 105(1):96-106.

Perlmutter, A. 1939. A biological survey of the salt waters of Long Island, 1938. Section 1. An ecological survey of young fish and eggs identified from tow-net collections. Suppl. 28th Ann. Rep. N.Y. Cons. Dept. Part 2. pp. 11-71.

Perlmutter, A., W. S. Miller, and J. C. Poole. 1956. The weakfish (Cynoscion regalis) in New York waters. N.Y. Fish Game J. 3(1):1-43.

Price, K.S., Jr. 1962. Biology of the sand shrimp, Crangon septemspinosa, in the shore zone of the Delaware Bay region. Chesapeake Sci. 3(4):244-255.

Raney, E. C. 1952. The life history of the striped bass, Roccus saxatilis (Walbaum). Pages 5-97 In The striped bass Roccus saxatilis. E. C. Raney, E. F. Tresselt, E. H. Hollis, V. D. Vladykov, and D. H. Wallace. Bull. Bingham Oceanogr. Collect. Vol. 14, Art. 1.

Ristich, S. S., M. Crandall, and J. Fortier. 1977. Benthic and epibenthic macroinvertebrates of the Hudson River. I. Distribution, natural history and community structure. Estuar. Coast. Mar. Sci. 5:255-266.

Sandifer, P. A. 1972. Morphology and ecology of Chesapeake Bay decapod crustacean larvae. Ph.D. Dissertation., Univ. Va., Charlottesville. 532 pp.

Schubel, J. R. 1974. Effects of exposure to time-excess temperature histories typically experienced at power plants on the hatching success of fish eggs. Estuar. Coast. Mar. Sci. 2:105-116.

Scott, W. B. and E. J. Crossman. 1973. Freshwater Fishes of Canada. Ed. by J. C. Stevenson. Fisheries Res. Bd. Can., Ottawa, Can.

Talbot, G. B. 1966. Estuarine environmental requirements and limiting factors for striped bass. A Symposium on Estuarine Fishes. Am. Fish. Soc. Spec. Publ. No. 3:37-49.

Texas Instruments, Inc. (TI). 1973. Hudson River ecological study in the area of Indian Point. Second semiannual report. Prepared for Consolidated Edison Company of New York, Inc. Dallas, Texas.

Texas Instruments, Inc. (TI). 1975a. 1974 Hudson River Program. Ichthyoplankton data summary. Prepared for Consolidated Edison Company of New York, Inc. Dallas, Texas.

Texas Instruments, Inc. (TI). 1975b. Hudson River ecological study in the area of Indian Point. 1974 Annual Report Consolidated Edison Company of New York, Inc. Dallas, Texas.

Texas Instruments, Inc. (TI). 1976a. Ichthyoplankton data display. Prepared for Consolidated Edison Company of New York, Inc. Dallas, Texas.

Texas Instruments, Inc. (TI). 1976b. 1974 Hudson River Program. Fisheries data display, Volume II. Prepared for Consolidated Edison Company of New York, Inc. Dallas, Texas.

Texas Instruments, Inc. (TI). 1976C. Fisheries data display, Volume II. Prepared for Consolidated Edison Company of New York, Inc. Dallas, Texas.

Texas Instruments, Inc. (TI). 1976d. Hudson River ecological study in the area of Indian Point. Thermal Effects Report. Prepared for Consolidated Edison Company of New York, Inc. Dallas, Texas.

Texas Instruments, Inc. (TI). 1976e. Fisheries survey of the Hudson River, Volume IV. Prepared for Consolidated Edison Company of New York, Inc. Dallas, Texas.

Texas Instruments, Inc. (TI). 1976f. Hudson River ecological study in the area of Indian Point. 1975 Annual Report. Prepared for Consolidated Edison Company of New York, Inc. Dallas, Texas.

Texas Instruments, Inc. (TI). 1977. 1976 Ichthyoplankton data display. Prepared for Consolidated Edison Company of New York, Inc. Dallas, Texas.

Turner, J. L. and D. W. Kelley. 1966. Ecological studies of the Sacramento - San Joaquin Delta. Part II. Fishes of the Delta. State of California. The Resources Agency. Department of Fish and Game. Sacramento, Calif. Fish Bulletin 136. 166 pp.

United States Environmental Protection Agency (EPA). 1977. Draft Interagency 316(a) Technical Guidance Manual and Guide for Thermal Effects Sections of Nuclear Facilities Environmental Impact Statements. Washington, D.C. 79 pp.

Vladykov, V. D. and J. R. Greeley. 1963. Order Acipenseroidei. Pages 24-60 In Fishes of the Western North Atlantic. Part 3. Mem. Sears Found. Mar. Res. (1):630.

Williams, A. B. 1965. Marine decapod crustaceans of the Carolinas. U.S. Fish Wildl. Serv., Fish. Bull. 65(1):298.

Wyllie, M. C., E. R. Holmstrom, and R. K. Wallace. 1976. Temperature preference, avoidance, shock, and swim speed studies with marine and estuarine organisms from New Jersey. Report for the period January-December 1975. Prepared by Ichthyological Associates, Inc. Bulletin No. 15. Public Service Electric and Gas.

Chapter 6
COST-BENEFIT ANALYSIS

CHAPTER 6: COST-BENEFIT ANALYSIS FOR CLOSED-CYCLE COOLING AT THE BOWLINE POINT GENERATING STATION

Incorporated by reference into this 316(a) demonstration are Exhibits 23 and 28 in Docket II-C/WP-77-1 of the consolidated adjudicatory hearing for the major Hudson River electric generating stations, respectively entitled "Bowline Point Generating Station: Engineering, Environmental (Nonbiological), and Economic Aspects of a Closed-Cycle Cooling System" and "Report on Cost-Benefit Analysis of Operation of Hudson River Steam-Electric Units with Once-Through and Closed-Cycle Cooling Systems." These exhibits show that the installation of cooling towers at the Bowline Point plant will entail capital costs of $77,820,000 and annual levelized operating and owning costs of $21,959,753 per year.

Chapters 4 and 5 of this demonstration have shown that the thermal discharge from the Roseton plant has not caused prior appreciable harm to the aquatic biota of the Hudson River estuary, nor has it interfered with the protection and propagation of a balanced indigenous community of shellfish, fish, and wildlife in and on this waterbody. Consequently, the installation of cooling towers at this plant to drastically reduce the thermal discharge would entail incurring great economic costs to achieve no appreciable benefit to the aquatic biota. Therefore, it can only be concluded that the costs of installing closed-cycle cooling at the Bowline Point plant are wholly disproportionate to the benefits to be achieved from the reduction of the thermal discharge from this plant.

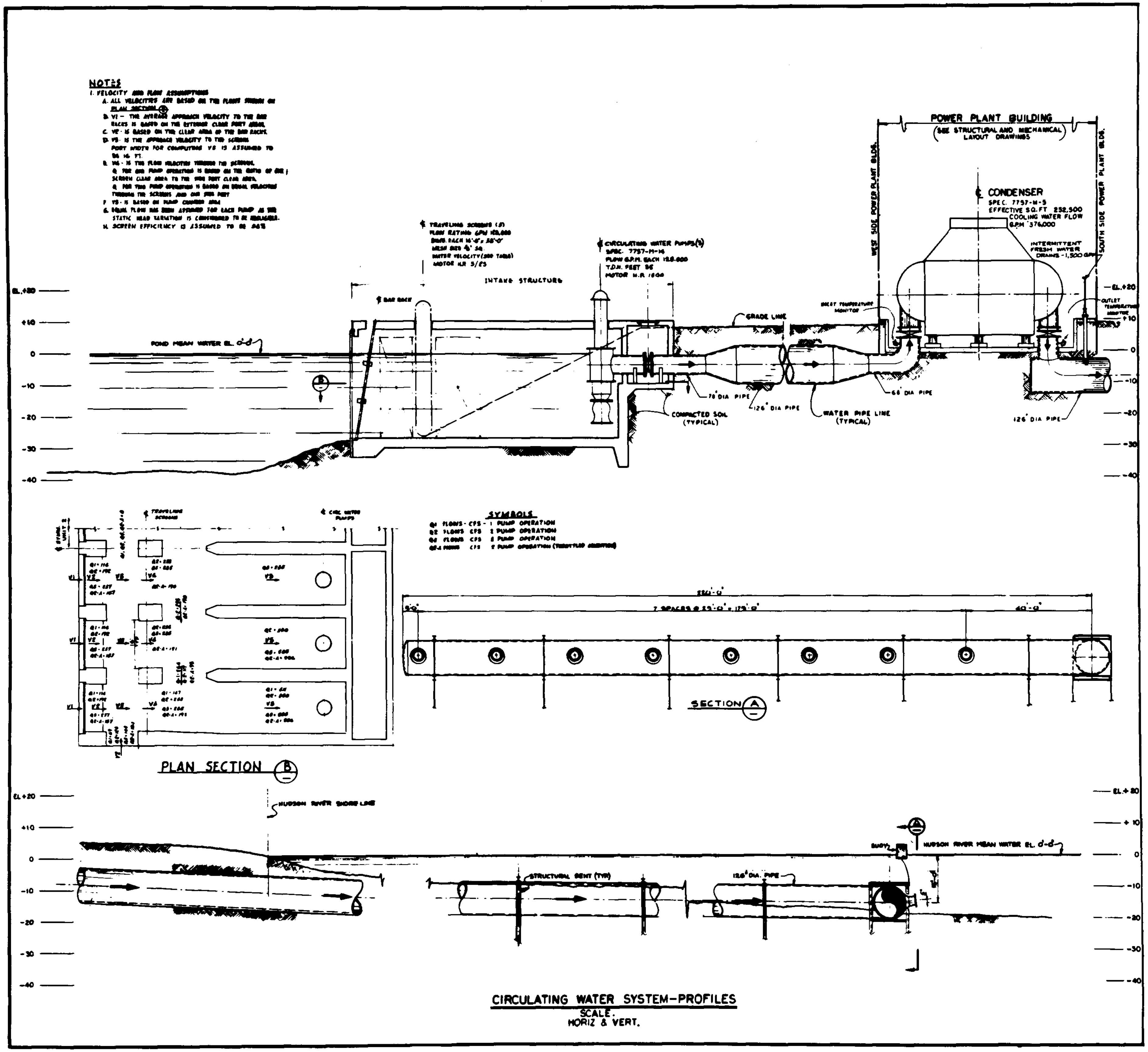


Figure 3.2-2

CIRCULATING WATER SYSTEM
BOWLINE POINT GENERATING STATION

Mitigating Aquatic Impacts at
Bowline Point
Indian Point Units 2 and 3
and
Roseton
Generating Stations

THE ISSUES AND ALTERNATIVE SOLUTIONS

January 1979

Mitigating Aquatic Impacts at
Bowline Point
Indian Point Units 2 and 3
and
Roseton
Generating Stations

THE ISSUES AND ALTERNATIVE SOLUTIONS

January 1979

Introduction

The use of large amounts of Hudson River water to cool the condensers at the Bowline Point, Indian Point, and Roseton generating stations has associated with it some potentially adverse impact on fish due to entrainment and impingement. Entrainment is the passage of the early life stages of fish through the plant cooling water system, during which some are killed. Impingement is the entrapment of small fish on the intake screens that prevent debris from entering the cooling water system. These impacts are generally confined to fish during their first year of life.

Central Hudson Gas and Electric Corporation, the Consolidated Edison Company of New York, Inc., Orange and Rockland Utilities, Inc., and the Power Authority of the State of New York (the Utilities) are engaged currently in an extended consolidated adjudicatory hearing before Region II of the federal Environmental Protection Agency (EPA) to consider, among other matters, the extent of the entrainment and impingement impact of their plants and to determine the best way to mitigate that impact if mitigation is found to be necessary. The purpose of this paper is to summarize the issues and to suggest a practical alternative that is more in the public interest than continuing with the adjudicatory hearing.

The Issues

The principal issue in the current EPA adjudicatory hearing is a determination of the best technology available for minimizing adverse environmental impact. The EPA Administrator and the EPA General Counsel have ruled that this statutory test requires a determination that the costs of any mitigation measures should not be substantially disproportionate to their benefits. This is consistent with the President's recently announced policy to take steps to curb inflation.

The Utilities submitted extensive testimony to EPA in July 1977 which concludes that the impacts of the existing cooling systems are not biologically significant, will not result in significant reductions in the fish populations of the Hudson River, and do not justify the construction of expensive and large cooling towers. Their testimony is based on many years of biological investigations of the Hudson River, the most extensive study of its kind ever conducted on a single estuarine waterbody.

EPA has not yet submitted its direct testimony in the proceeding. However, an EPA staff position paper prepared before the Utilities' biological studies were completed and submitted asserts that the impacts are significant, and warrant the installation of new closed cycle cooling systems (cooling towers) at all of the plants to replace the existing once through systems. In the EPA staff's view, closed cycle cooling is the best available technology for the intake structures to minimize adverse impact. Apparently, EPA staff has made no cost-benefit study however, and staff has maintained that cost-benefit considerations are irrelevant.

The Utilities' testimony includes an evaluation of the costs and benefits of closed cycle versus once through cooling, concluding that the costs of retrofitting closed cycle cooling systems exceed by more than 100 fold any quantifiable benefits that would be realized. This is based on the small impacts of the plants on fish, a capital cost of approximately $372 million for the cooling towers that would have to be constructed as part of the closed cycle systems, and annual levelized customer revenue requirements of approximately $109 million. The Utilities point out that more than 720,000 additional barrels of oil per year would be consumed in order to make up for the efficiency losses resulting from cooling towers.

The Utilities' testimony also includes studies of methods to mitigate some of the impacts resulting from entrainment and impingement. Those studies were undertaken in order to determine whether alternatives to cooling towers might be available in the event that the biological studies concluded that significant adverse impacts take place.

The impingement mitigation device with the highest proven potential appears to be traveling screens equipped with troughs (Ristroph screens). These screens, illustrated in Figure 1, reduce impingement impact by collecting impinged fish in the troughs, from which they can be returned to the river. Virginia Electric Power Company has tested these screens for several years and reports survivals exceeding 90%. They cost substantially less than cooling towers (less than $15 million compared to $372 million) and do not involve the energy penalty implications of cooling towers. A recent study by the Utilities on the potential of Ristroph screens in mitigating impacts is discussed in the following section.

Another type of device, angled screens, has also been studied by the Utilities in laboratory flume tests and shows potential as an impingement mitigation device. Angled screens reduce impingement impact by diverting fish approaching the intakes into a bypass system, from which they are returned to the river. The laboratory tests indicated that up to 96% of the fish approaching the angled screens were successfully diverted. However, angled screens have not been field tested, making it impossible to estimate confidently the exact level of mitigation that would be realized under field conditions.

Extensive testing and field observations have shown that entrainment survival is substantially more than assumed prior to testing. The EPA permit determinations were based on the assumption that substantially all entrained organisms would be killed during passage through the plant. Recent biological studies show that this is not the case and that survival of entrained striped bass ranged from 38% to 83%, depending on life stage. Survival of other species is comparably high.

Mitigation Alternatives

The Utilities recently conducted a modeling study to ascertain the extent to which modification of the intakes at the four Hudson River plants to mitigate impingement impact would mitigate overall impact, and to compare the results with the level of mitigation that would be achieved with cooling towers at the same plants. The study utilized entrainment survival rates derived from the recent biological studies. Impacts on striped bass, white perch, and Atlantic tomcod were examined, as these are the species most impacted by the power plants.

The extent of mitigation that would be achieved with Ristroph screens at Bowline Point and Indian Point Units 2 and 3 was calculated based on a 75% efficiency level, which represents a conservative estimate of the lowest efficiency level for such devices that would be expected on the Hudson River. Installation of Ristroph screens at Roseton is not warranted, since impingement is not significant at that plant. The results, summarized in the attached table, show that with installation of Ristroph screens the overall impact on adult striped bass would be reduced by 41% compared to the impact expected with continued use of once through cooling. The reduction in impact would be 51% of that which would be attained by the installation of cooling towers at all of the plants. In other words, installation of the Ristroph screens would achieve more than 50% of the benefits of six cooling towers, at about 5% of the costs.

With respect to adult white perch, installation of Ristroph screens at the three plants would reduce the overall impact by 58% compared to the impact expected with continued use of once through cooling, and would be 64% as effective in reducing impacts as the installation of cooling towers at all plants. Impingement mitigation resulting from the installation of Ristroph screens at the three plants would be about 27% as effective as construction of cooling towers in reducing impacts on Atlantic tomcod.

The comparisons of the effectiveness of these screens and cooling towers are relatively insensitive to the controversial question of the extent of the compensatory reserve of the fish populations.

Conclusions

1. Cooling tower installation would involve large capital expenditures which would necessarily have to be borne by the Utilities' customers in increased rates.

2. The costs of towers far outweigh their environmental benefits, with commensurate inflationary effects. Towers would also have substantial energy requirements.

3. Ristroph screens have been proven to be very efficient in reducing impingement impacts. When compared to closed cycle cooling at the Hudson River plants, installation of Ristroph screens at Bowline Point and Indian Point Units 2 and 3 would be very effective in minimizing impacts on fish.

4. Ristroph screens installed at Bowline Point and Indian Point Units 2 and 3 would cost only about 5% of the amount necessary to install cooling towers at the Utilities'

plants. Ristroph screens would achieve more than 50% of the benefits of cooling towers, at a low operating cost, and with no impact on oil consumption.

5. Ristroph screens could be designed and installed in a relatively short period of time. On the other hand, if one or more cooling towers were found to be required after the current EPA proceedings are concluded in the early 1980s, it would still take four or more additional years to install any cooling towers required.

Given the above factors, it is reasonable to consider whether an alternative to the current lengthy adjudicatory process might be in the public interest, including the interest of fishery protection. Such an alternative program could be:

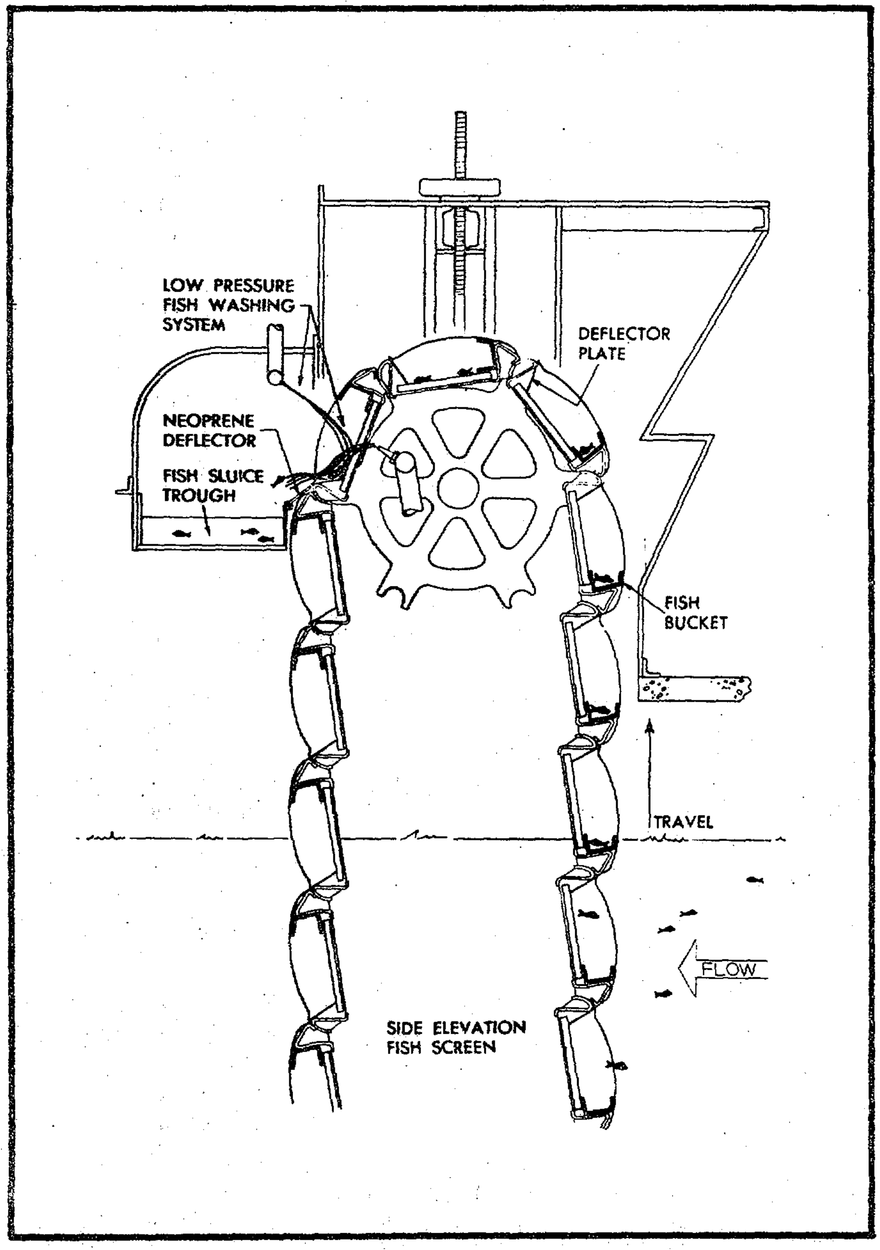
1. Immediate initiation by the Utilities of a program to install Ristroph screens at Bowline Point and Indian Point Units 2 and 3 so that operation could begin as early as 1981 or 1982.

2. Evaluation of the effectiveness of the installed screen devices for a two-year period while continuing to monitor the overall impact of power plant operation on the Hudson River fishery.

3. Suspension of the current adjudicatory proceedings pending consideration of the effectiveness of the screens actually installed on the River.

The above program would immediately benefit the aquatic environment. It offers a realistic demonstration of mitigation of fishery impacts without the need to incur substantially increased expenditures, more oil consumption, or increased rates. Finally, given that NPDES permits must be renewed every five years, the responsible regulatory authorities will be fully capable of monitoring developments, and requiring any additional modifications in the future as might be justified.

Figure 1



Schematic diagram of the Ristroph traveling fish screen.

REDUCTIONS IN ADULT STRIPED BASS, WHITE PERCH AND ATLANTIC TOMCOD POPULATIONS UNDER VARIOUS MITIGATION ALTERNATIVES

Mitigation Alternative	Percent Reduction in Adult Population Striped Bass	White Perch	Atlantic Tomcod
Once through cooling at all plants	7.6	21.6	2.7
75% impingement mitigation at Bowline Point and Indian Point Units 2 and 3	4.5	9.0	2.1
Closed cycle cooling at all plants	1.4	2.2	0.6

COMPARISON OF MITIGATION ACHIEVED WITH 75% IMPINGEMENT MITIGATION AT BP, IP2, AND IP3 TO THAT ACHIEVED WITH CLOSED CYCLE COOLING AT ALL PLANTS

	Impact Reduction (%)		% Effectiveness
Species	Impingement Mitigation	Closed Cycle Cooling	Impingement Mitigation vs. Closed Cycle Cooling
Striped bass	3.1	6.2	51
White perch	12.6	19.4	64
Atlantic tomcod	0.6	2.1	27

TECHNICAL SUMMARY

Mitigating Aquatic Impacts at
Bowline Point
Indian Point Units 2 and 3
and
Roseton
Generating Stations

TECHNICAL SUMMARY

Introduction

The principal issue in the current consolidated adjudicatory hearing of Central Hudson Gas and Electric Corporation, the Consolidated Edison Company of New York, Inc., Orange and Rockland Utilities, Inc., and the Power Authority of the State of New York before Region II of the federal Environmental Protection Agency (EPA) is a determination of the best technology available for minimizing adverse environmental impact under Section 316(b) of the Clean Water Act. The purpose of this paper is to summarize the technical issues related to that determination.*

Impact of Once Through Cooling

Central to a determination of the best technology available for minimizing adverse environmental impact at the Hudson River power plants is an evaluation of the entrainment and impingement impact of those plants. The Utilities submitted extensive testimony in July 1977 which concludes that the impacts of the existing once through cooling systems are not biologically significant and will not result in significant

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* For a general discussion of the issues, see "Mitigating Aquatic Impacts at Bowline Point, Indian Point Units 2 and 3, and Roseton Generating Stations - The Issues and Alternative Solutions."

reductions in the fish populations of the Hudson River.

(Entrainment)

The early life stages of some Hudson River fishes are susceptible to entrainment in power plant cooling water circulating systems. The Utilities have conducted extensive farfield and nearfield sampling efforts to determine the distribution and abundance of these early life stages, as well as the relative abundances entrained at the plants (1). Whereas it was formerly assumed that substantially all entrained organisms would be killed (2), the Utilities have shown that many or most survive. Survival of entrained striped bass, for example, ranges from 38 to 83%, depending on life stage (3). Survival of other species is comparably high.

(Impingement)

Small fishes which have grown beyond entrainable size are subject to impingement on the intake screens that prevent debris from entering the plant. The majority of the fishes that are actually impinged are juveniles ranging in size from approximately 2 to 5 inches in total length. The Utilities have conducted extensive studies of the abundances of impinged fishes, the causal factors in impingement, and fish survival following impingement (4).

(Compensation)

Power plant induced mortality of fishes attributable to entrainment and impingement is offset by the natural phenomenon of compensation, which is the tendency of populations of living organisms to experience a decrease in death rate or increase in birth rate, or both, as population density declines. Compensation leads to population stabilization.

The Utilities have conducted extensive studies of the theory of compensation, its role in fisheries maintenance, the compensatory mechanisms exhibited in Hudson River striped bass populations, and the quantification of the compensatory reserve in Hudson River striped bass (5). The issue in the current proceeding is not the functioning of compensation to offset power plant and other losses, but rather the actual level of the compensatory reserve of the population.

(Impact Prediction)

The impact of entrainment and impingement on the Hudson River striped bass population is evaluated using the real time life cycle (RTLC) model, which mathematically represents the interplay of mass transport, biological and plant operating parameters to simulate the development of the striped bass population from egg deposition through adulthood (6). The empirical data collected by the Utilities is used as input to the model to arrive at a prediction of long term population effects (7).

Using the RTLC model and the empirical data, the Utilities' studies indicate that continued operation of Bowline Point, Indian Point and Roseton with once through cooling over the next 40 years would cause a reduction in the Hudson River striped bass population of about 8% (8).

The impact of entrainment and impingement on white perch and Atlantic tomcod populations is evaluated by application of an equilibrium reduction equation (ERE), which was derived from studies of the theory of population dynamics in fish populations (9). The empirical data collected by the Utilities are used to determine the values of the parameters of the equation (10).

Mitigating Measures Studies

The Utilities have continued to study the survival of entrained organisms and have obtained considerable confirmatory evidence that substantial numbers survive entrainment in the cooling water systems (11).

They have also studied methods to mitigate impingement impacts by means of evaluation of work being done by other groups and by conducting engineering feasibility studies, laboratory studies, field studies and modeling studies specific to the Hudson River. Of the mitigation devices examined, the one with the highest proven potential appears to be traveling screens equipped with troughs (Ristroph screens). Angled screens have shown potential in the laboratory, but have not been field tested. Barrier nets have also shown potential in those situations where they can be successfully deployed (12).

(Ristroph Screens)

Ristroph or bucket screens use a conventional traveling screen modified with troughs for the retention of impinged fishes. The fish are then washed from the moving troughs and transported back to the receiving waters. Virginia Electric Power Company (VEPCO) has tested this type of screening device for several years at its Surrey plant on the James River, and has reported survivals exceeding 90% for striped bass and white perch (13).

The Utilities have conducted survival studies of fish impinged on the existing intake screens and found that many fish could survive the impingement process were they returned to the river (14). They have also conducted a limited field study of a bucket screen system at one intake screen of Indian Point Unit 1 (15). Striped bass survival was comparable to that achieved by VEPCO, but white perch survival was only about 45%. However, it is expected that these survivals could be increased significantly by improved operation and collection procedures. A minimum of 75% survival would be expected.

(Angled Screens)

The angled screen diversion system is designed to include flush mounted traveling screens that are angled to the intake flow and a bypass system that serves to guide fish away from the plant intake. The velocity gradient developed along the face of the screens elicits an avoidance response in fishes and allows them to be bypassed safely.

The Utilities have conducted experimental testing of angled screens in a laboratory flume which showed that 96% of the fish were successfully diverted (16). They have also conducted conceptual engineering studies of the feasibility of retrofitting angled screens at Indian Point and Bowline Point (17).

Since angled screens have not been field tested, it is not possible to estimate accurately the exact level of mitigation that would be achieved without some prototype effort.

(Cooling Towers)

An EPA staff position paper published before the results of the Utilities' biological studies were available asserted that cooling towers should be retrofitted at the Hudson River plants (18). The Utilities examined this alternative and submitted testimony to show that retrofitting cooling towers would have an estimated capital cost of $372 million and annual levelized revenue requirements of approximately $109 million (19). They concluded that the costs are more than 100 times any quantifiable benefits that would be realized (20).

Effectiveness of Alternative Mitigating Measures

In order to demonstrate the effectiveness of the alternative intake structure technologies described herein in reducing power plant impact, calculations were made to compare the reduction in indicated plant impact on Hudson River populations of striped bass, white perch, and Atlantic tomcod achievable with the modified intakes with the reduction estimated to result from installation of cooling towers (21). Two somewhat different methodologies were employed in these calculations, one for striped bass and another for white perch and Atlantic tomcod.

Impact estimates for striped bass were obtained from the RTLC model. The input parameters required for model simulation were based on 1974 data as reported in McFadden and Lawler (22). Impact estimates for white perch and Atlantic tomcod were obtained from the ERE using data reported earlier (23), which was adjusted to reflect average conditions at the plants over the period from 1976 through 2013 (24). Each method was applied, assuming continued use of once through cooling and also operation with cooling towers, so that comparisons of the available technologies could be developed. The value of the compensation parameter alpha was also varied, but this had almost no effect on the relative effectiveness of the alternative technologies (25).

As compared to once through cooling, installation of cooling towers at Indian Point, Bowline Point, and Roseton would reduce projected impacts as follows:

Striped Bass	81%*
White Perch	90%
Atlantic Tomcod	78%

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* I.e.: From Table 5 of LMS (1978) for an alpha of 5, (7.57-1.43)/7.57 = 81%

Calculations for white perch and Atlantic tomcod were based on data from Tables 6 and 7, respectively, of LMS (1978).

Installation of 75% efficient Ristroph screens at Bowline Point and Indian Point Units 2 and 3 would reduce projected impacts as follows:

Striped Bass	41%*
White Perch	58%
Atlantic Tomcod	21%

Comparatively, mitigation of the impingement impact on striped bass with Ristroph screens at Indian Point Units 2 and 3 and Bowline Point would be 51% as effective in reducing impact as installation of cooling towers at all of the plants. Impingement mitigation would be 64% as effective as cooling towers for white perch, and 27% as effective for Atlantic tomcod.

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* I.e.: From Table 5 of LMS (1978) for an alpha of 5, (7.57-4.50)/7.57 = 41% where 4.50 is estimated based on the Roseton results.

Calculations for white perch and Atlantic tomcod were based on data from Tables 6 and 7, respectively, of LMS (1978).

References

1. CHG&E 1977(a); Chapter 9
   Con Ed and PASNY 1977(a); Chapter 9
   O&R 1977(a); Chapter 9
   McFadden 1977; Sections 6 and 8
   McFadden and Lawler 1977; Appendix B

2. USNRC 1975; Chapter V

3. EAI 1977; Chapter 3

4. CHG&E 1977(a); Chapter 10
   Con Ed and PASNY 1977(a); Chapter 10
   O&R 1977(a); Chapter 10
   McFadden 1977; Sections 6 and 9
   King et al 1977

5. McFadden 1977; Section 10
   McFadden and Lawler 1977; Parts 2 and 3

6. McFadden 1977; Section 12
   McFadden and Lawler 1977; Part 3

7. McFadden 1977; Section 12
   McFadden and Lawler 1977; Part 3

8. McFadden and Lawler 1977; Part 3

9. McFadden and Lawler 1977; Part 2

10. McFadden and Lawler 1977; Part 2

11. EAI 1978(a)
    EAI 1978(b); Chapter 4
    EAI 1978(c)

12. LMS 1978(a)

13. White and Brehmer 1976
    Brehmer 1978

14. O&R 1977(a)
    CHG&E 1977(a)
    King et al 1977

15. TI 1978

16. S&W 1976(a)

17. S&W 1976(a), 1976(b)

18. U.S. EPA 1977

19. CHG&E et al 1977
CH 1977(b); Chapter 2
Con Ed and PASNY 1977(b); Chapter 3
O&R 1977(b); Chapter 3

20. CHG&E et al 1977; Chapter 5

21. LMS 1978(b)

22. McFadden and Lawler 1977; Part 3

23. McFadden and Lawler 1977; Part 2

24. LMS 1978(b); Section II

25. LMS 1978(b); Section III

References Cited

Brehmer, Morris L., personal communication, 1978.

Central Hudson Gas & Electric Corporation. 1977(a). Roseton Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota.

Central Hudson Gas & Electric Corporation. 1977(b). Roseton Generating Station. Engineering, environmental (non-biological), and economic aspects of a closed-cycle cooling system.

Central Hudson Gas & Electric Corporation, Consolidated Edison Company of New York, Inc., Orange and Rockland Utilities, Inc. and Power Authority of the State of New York. 1977. Report on cost-benefit analysis of operation of Hudson River steam-electric units with once-through and closed-cycle cooling systems.

Consolidated Edison Company of New York, Inc. and Power Authority of the State of New York. 1977(a). Indian Point Unit No. 2, Indian Point Unit No. 3. Near-field effects of once-through cooling system operation on Hudson River biota.

Consolidated Edison Company of New York, Inc. and The Power Authority of the State of New York. 1977(b). Indian Point Unit Nos. 2 and 3. Engineering, environmental (non-biological), and economic aspects of a closed-cycle cooling system.

Ecological Analysts, Inc. 1977. Survival of entrained ichthyoplankton and macroinvertebrates at Hudson River power plants. Prepared for: Central Hudson Gas & Electric Corporation, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1978(a). Bowline Point Generating Station entrainment survival studies 1977 annual report. Prepared for: Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1978(b). Indian Point Generating Station entrainment survival and related studies 1977 annual report. Prepared for: Consolidated Edison Company of New York, Inc.

Ecological Analysts, Inc. 1978(c). Roseton Generating Station entrainment survival studies 1977 annual report - draft. Prepared for: Central Hudson Gas and Electric Corporation.

King, Lawrence R., Jay B. Hutchison, Jr. and Thomas G. Huggins. 1977. Impingement survival studies on white perch, striped bass, and Atlantic tomcod at three Hudson River power plants. Presented at the Fourth National Workshop on Entrainment and Impingement, December 5, 1977.

Lawler Matusky & Skelly Engineers. 1978(a). 1977 Hudson River Aquatic Ecology Studies at the Bowline Point Generating Station. Prepared for: Orange and Rockland Utilities, Inc.

Lawler Matusky & Skelly Engineers. 1978(b). Mitigation of impingement impact at Hudson River power plants. Prepared for: Consolidated Edison Company of New York, Inc.

McFadden, J.T. 1977. Influence of Indian Point Unit 2 and other steam electric generating plants on the Hudson River Estuary, with emphasis on striped bass and other fish populations. Prepared for: Consolidated Edison Company of New York, Inc.

McFadden, J.T. and J.P. Lawler. 1977. Supplement I to influence of Indian Point Unit 2 and other steam electric generating plants on the Hudson River Estuary, with emphasis on striped bass and other fish populations. Prepared for: Consolidated Edison Company of New York, Inc.

Orange and Rockland Utilities, Inc. 1977(a). Bowline Point Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota.

Orange and Rockland Utilities. 1977(b). Bowline Point Generating Station. Engineering, environmental (non-biological), and economic aspects of a closed-cycle cooling system.

Stone & Webster Engineering Corporation. 1976(a). Final report Indian Point flume study. Prepared for: Consolidated Edison Company of New York, Inc.

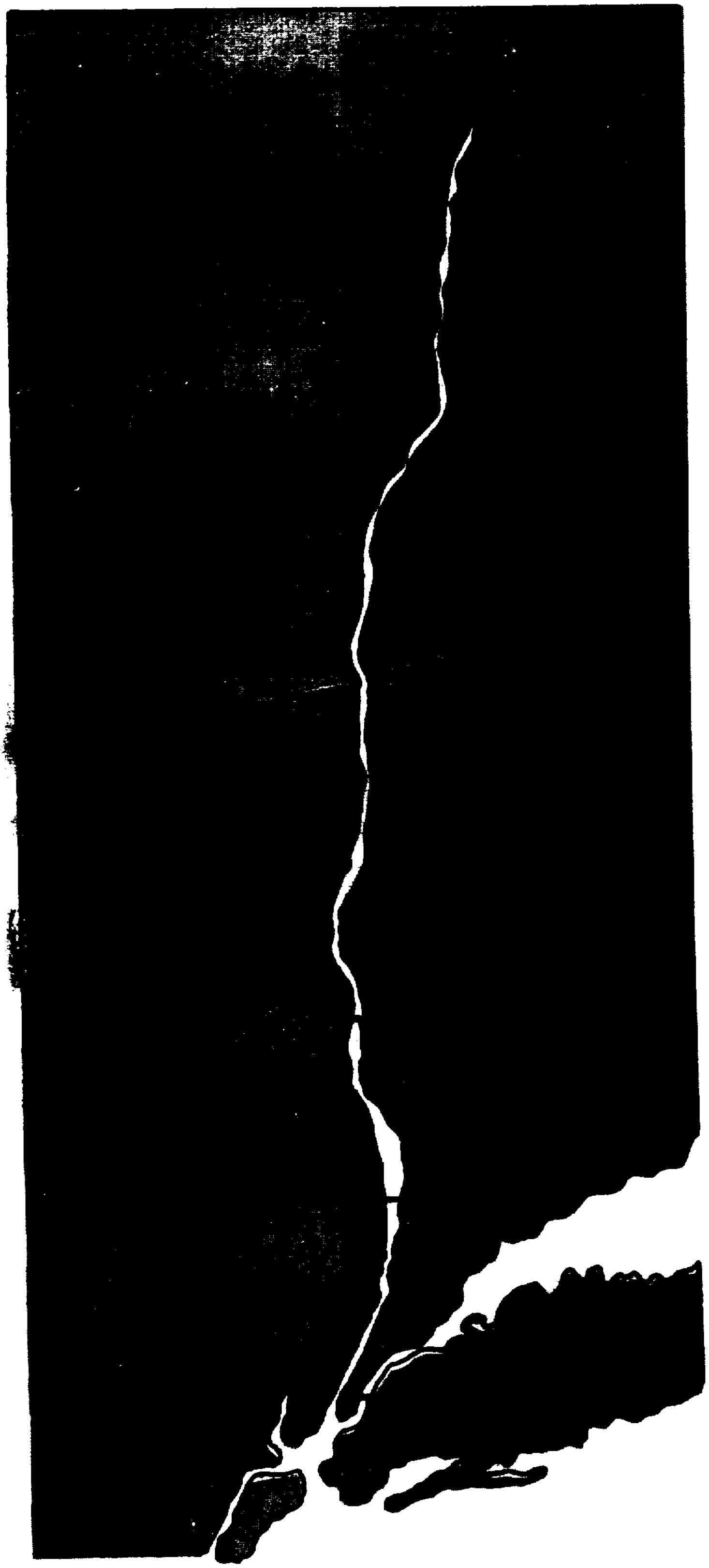
Stone & Webster Engineering Corporation. 1976(b). Alternative intake design with fish handling capabilities Bowline Point Generating Station Units 1 and 2. Prepared for: Orange and Rockland Utilities, Inc.

Texas Instruments Incorporated. 1978. Initial and extended survival of fish collected from a fine mesh continuously operating traveling screen at the Indian Point Generating Station for the period 15 - 22 December 1977. Prepared for: Consolidated Edison Company of New York, Inc.

U.S. Environmental Protection Agency. 1977. Untitled document presenting EPA Region II's position regarding the reasons for its decision to require closed cycled cooling at the Hudson River plants. Distributed to all parties in the proceeding by letter dated November 4, 1977.

U.S. Nuclear Regulatory Commission. 1975. Final environmental statement related to operation of Indian Point Nuclear Generating Plant Unit No. 3. Consolidated Edison Company of New York, Inc. Docket No. 50-286. Volume 1. Chapter V.

White, J.C. and M.L. Brehmer. 1976. Eighteen-month evaluation of the Ristroph Traveling Fish Screens. Presented at the Third National Workshop on Entrainment & Impingement, February 24, 1976.



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DEPARTMENT OF THE ARMY
NEW YORK DISTRICT
CORPS OF ENGINEERS
26 FEDERAL PLAZA
NEW YORK, N.Y. 10278

FINAL ENVIRONMENTAL IMPACT STATEMENT

JAN. 1981

BOWLINE POINT GENERATING STATION

Haverstraw, New York

DEPARTMENT OF THE ARMY
NEW YORK DISTRICT
CORPS OF ENGINEERS
26 FEDERAL PLAZA
NEW YORK, N.Y. 10278

SUMMARY

BOWLINE POINT GENERATING STATION
HAVERSTRAW, NEW YORK

( ) Draft (XX) Final Environmental Statement

Responsible Office: Department of the Army
New York District, Corps of Engineers
26 Federal Plaza
New York, N.Y. 10007

1. Nature of Action: (XX) Administrative ( ) Legislative

2. Description of Action

The New York District, Corps of Engineers is considering several alternative actions in connection with the continued operation of the Bowline Point and Roseton Generating Stations. Both stations are in full commercial operation within the electrical supply system of the New York Power Pool. Permits authorizing the construction of intake and discharge structures and other activities related to the construction of these stations were issued by the District in 1970 and 1971. The District now has legal obligations to evaluate the environmental impacts of the Bowline Point and Roseton Generating Stations and to determine the appropriate course of action regarding their continued operation. Alternatives available to the District are (1) to retain unaltered, (2) to modify, (3) to suspend or (4) to revoke the permits issued by the District.

3a. Environmental Impacts

The environmental impacts associated with each of the alternatives enumerated above are described in the present statement. The analysis of impacts encompasses the cumulative effects associated with all existing power plants on the Hudson River. In the analysis of cumulative effects, particular attention is directed towards the Bowline Point and Roseton Generating Stations, both 1,200 megawatt oil-fueled power plants on the Hudson River located, respectively, at Haverstraw and Newburgh, New York.

Operation of the Bowline Point and Roseton power plants entails the consumption of fuel oil and the withdrawal of water from the Hudson River for condenser cooling and other station purposes. Both stations release airborne and waterborne contaminants and generate noise and small quantities of solid wastes. The power plants are conspicuous features in their respective settings. Substantial property taxes accrue to the localities in which the generating stations are situated.

3b. Adverse Environmental Impacts

Concern over the power plants sited on the Hudson River has centered primarily on potential adverse impacts on the aquatic ecosystem resulting from the operation of these plants. Impacts are associated principally with the entertainment of fish eggs and larvae through the power plant cooling systems and the impingement of juvenile fish on devices used to screen the water at the condenser intakes. Extensive research and field surveys over the past several years have been oriented heavily towards potential effects on striped bass (Monroe saxatilis). Notwithstanding these efforts, the extent to which the adult fish stocks within the Hudson River might be reduced if all existing power plants continue to operate with once-through cooling systems remains a matter of controversy. Staff members of the Utilities and their consultants have estimated the long-term reduction of adult stocks of several fish species to be as follows:

Striped bass - 2.6 to 10.8 percent
White perch - 0.2 to 14.0 percent
American shad- 0.1 to 4.0 percent

The staff of the U.S. Environmental Protection Agency, Region II and their consultants have reviewed the Utilities analyses. They have concluded that there are sufficient uncertainties about the quality of the data from the Hudson River and the applicability of the theory of population dynamics which is the Utilities' basis for predicting long-term impacts to cast considerable doubt on the validity of the entire Utilities' analysis. The staff of the U.S. Environmental Protection Agency has made no estimates of their own of the magnitude of potential long term impacts to fish populations, but analyses carried out by their consultants indicate that reductions in fish populations could be much greater than those predicted by the Utilities. The installation of evaporative close-cycle cooling systems at certain power plants on the river would reduce but not entirely eliminate the destruction of aquatic organisms from entrainment and impingement.

Monitoring of air quality in the area surrounding the Bowline Point station has revealed no instance when the ambient air quality standards of New York State have been exceeded since the initial operation of the plant. Monitoring at the Roseton station has shown that the New York State standards for ambient concentrations of sulfur dioxide are being exceeded occasionally. In addition, the Federal secondary standard for suspended particulates is being exceeded occasionally. Numerical simulations show no evidence of substantive cumulative effects on ambient air quality arising from the operation of the power plants on the Hudson River.

Numerical simulations indicate that water temperatures in excess of New York State criteria could occur in the Hudson River as a result of the cumulative thermal discharges from existing and proposed power plants.

Installation of closed-cycle cooling systems at the Bowline Point and Roseton stations would increase noise levels off site. In addition, the use of cooling towers could potentially cause icing and fogging in their vicinities and the formation of acidic mist from interactions of the tower plume and stack emissions, although the probability of these events occurring is expected to be low. The potential exists for damage to vegetation from salt drift from a cooling tower at the Bowline Point station but is unlikely in the vicinity of the Roseton station. The visibility of the power stations would be increased substantially by closed-cycle cooling systems, particularly if natural draft towers are installed.

4. Alternatives

Alternative actions that might be implemented with respect to the continued operation of either or both the Bowline Point and the Roseton generating stations are:

with the existing intake + discharge structures

(1) To retain unaltered the permit and related conditions as issued by the District,
(2) To modify the permit through the imposition of additional conditions relating to the operation of the station,
(3) To suspend the permit until closed-cycle cooling or other modifications are installed,
(4) To revoke the permit, forcing the abandonment of the station.

5. Comments on the Draft Environmental Statement Requested From

Federal Agencies

Advisory Council on Historic Preservation
Department of Agriculture
Department of Commerce
Department of Health, Education and Welfare
Department of Housing and Urban Development
Department of the Interior
Department of Transportation
Energy Research and Development Administration
Environmental Protection Agency
Federal Power Commission
Nuclear Regulatory Commission
Office of Economic Opportunity

New York State

New York State Department of Environmental Conservation
New York State Department of Parks and Recreation
New York State Department of Transportation
New York State Planning and Development Clearinghouse
Power Authority of the State of New York
Public Service Commission

Other Parties

Central Hudson Gas and Electric Corporation
Consolidated Edison Company of New York, Inc.
Environmental Defense Fund
Haverstraw Town Clerk
Haverstraw Village Clerk
Hudson River Fishermen's Association
Hudson River Sloop Restoration, Inc.
Hudson Valley Audubon Society
Interstate Sanitation Commission
Mid-Hudson Pattern for Progress, Inc.
National Audubon Society
Natural Resources Defense Council, Inc.
Niagara Mohawk Power Corporation
Oak Ridge National Laboratories
Orange and Rockland Utilities, Inc.
Port Authority of New York and New Jersey, Planning and Development Department
Regional Plan Association
Rockland County Clerk
Rockland County Department of Health
Rockland County Planning Board
Save Our Stripers, Inc.
Stony Point Town Clerk
Town of Haverstraw Planning Board
Tri-State Regional Planning Commission
Village of Haverstraw Planning Board
West Haverstraw Village Clerk

County Planning Departments

New York: Albany, Rensselaer, Greene, Columbia, Ulster, Dutchess, Orange, Putnam, Rockland, Westchester

New Jersey: Bergen, Hudson

6. Draft Environmental Statement filed with the Council on Environmental Quality on ______________.

7. Comments on the Draft Environmental Statement Received From

Federal Agencies

Department of Agriculture, Forest Service
Department of Agriculture, Soil Conservation Service
Department of Commerce, Assistant Secretary for Science and Technology
Environmental Protection Agency, Region II
Department of Health, Education and Welfare, Office of the Secretary
Department of Health, Education and Welfare, Region II
Department of Housing and Urban Development, Area Office
Department of the Interior, Office of the Secretary
Department of Transportation, Federal Highway Administration
Department of Transportation, Regional Representative of the Secretary

State of New York

Department of Environmental Conservation
Department of Law
Metropolitan Transportation Authority

Utilities

Central Hudson Gas and Electric Corporation
Consolidated Edison Company of New York, Inc.
Orange and Rockland Utilities, Inc.

Other Parties

National Audubon Society
Natural Resources Defense Council, Inc. on behalf of the Hudson River Fisherman's Association
Save Our Stripers, Inc.

8. Final Environmental Statement Filed with the U.S. Environmental Protection Agency on ____________.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

Page

U.S. Department of Health, Education and Welfare, Office of the Secretary

U.S. Department of the Interior, Office of the Secretary

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

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TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Concluded)

LIST OF FIGURES

LIST OF FIGURES (con't)

LIST OF FIGURES (CONCLUDED)

LIST OF TABLES

LIST OF TABLES (con't)

LIST OF TABLES (con't)

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LIST OF TABLES (CONCLUDED)

CHAPTER 1

PROJECT DESCRIPTION

1.01 This environmental impact statement relates principally to the operation of the Bowline Point Generating Station, a power plant located on the Hudson River in Haverstraw, New York. Consideration is given to the impacts associated with the Bowline Point station and to the cumulative impacts of all existing, projects on the river. The analysis presented in this report focuses also on the Roseton Generating Station, a second plant in commercial service located in Newburgh, New York. The U.S. Army, Corps of Engineers, New York District (the District) has legal responsibilities to review the impacts of operating the Bowline Point and the Roseton generating stations and, in each instance, to determine the appropriate course of action regarding the continued operation of these stations.

1.02 For the past several years, concern has been expressed over the operation of power plants sited along the Hudson River. This concern centers mainly on the potential adverse effects that each plant may exert individually on populations of striped bass and other fishes of the Hudson River as well as the combined effects of all of these power plants. Accordingly, the District, in assessing the environmental impacts resulting from the operation of the subject power plants, has devoted particular attention to matters relating to alternations of the aquatic ecosystem of the Hudson River and to the cumulative and synergistic effects that may arise from the operation of existing plants and future developments on the river.

NATURE OF PROJECT AND AUTHORITY

1.03 The Bowline Point Generating Station is located in the Village of West Haverstraw and the Town of Haverstraw, Rockland County, New York. The station consists of two oil-fueled steam electric generating units and related facilities, constructed by Orange and Rockland Utilities, Inc. (referred to as Orange and Rockland throughout this document). The generating units, designated Units No. 1 and No. 2, are each rate at a nominal 600 megawatts* and are currently in commercial service. The Bowline Point Generating Station is owned jointly by Orange and Rockland and Consolidated Edison Company of New York (Con Edison).

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*Unless otherwise specified, the term megawatt denotes megawatt-electric throughout this document.

1.04 On 18 February 1970, Orange and Rockland applied to the District for a Department of the Army permit under Section 10 of the River and Harbor Act of 1899 (30 Stat. 1151; 33 U.S.C. 403), seeking authorization to dredge an inlet channel, to install discharge piping and construct a mooring facility, all in the navigable waters of the Hudson River in Rockland County, New York. The District prepared and circulated a draft environmental statement (filed with the Council on Environmental Quality on 4 October 1972) relating to the proposed work. The District subsequently revised and recirculated the draft environmental statement on 23 August 1973.

1.05 The District issued the requested permit on 12 July 1971. Construction work on Bowline Point Unit No. 1 was completed and the unit was brought into commercial service in September 1972. Unit No. 2 was brought into commercial service in May 1974.

1.06 On 29 December 1972, the Hudson River Fishermen's Association, Inc., together with other plaintiffs, filed a complaint in U.S. District Court, Southern District of New York (the Court) alleging that the withdrawal of water by the Bowline Point units for condenser cooling purposes would result in serious damage to the environment, including the entrainment of substantial numbers of striped bass eggs, larvae and juveniles. The plaintiffs alleged further that the District had wrongfully issued the above mentioned permit in that its issuance had not been preceded by the submission of a final environmental impact statement in accordance with the requirement of the National Environmental Policy Act of 1969 (42 USC, 4321 et seq.).

1.07 On 9 January 1974, the Court sanctioned a consent decree entered by consent of the Hudson River Fishermen's Association and the District, together with Orange and Rockland and Con Edison. In accordance with the terms of the decree, certain restrictions were imposed on the operation of the Bowline Point Units No. 1 and No. 2 during the last 10 days in May and the months of June and July of 1974. Further, the District agreed to prepare and circulate a draft environmental statement related to the construction and operation of the Bowline Point Generating Station, considered in conjunction with other existing and proposed facilities on the Hudson River. In response to this provision, the District has sponsored a study* by the Oak Ridge National Laboratory to evaluate the effects of the Bowline Point station and cumulative effects on (1) the population of stripped bass in the Hudson River, taking into account information that has become available since the issuance in 1972 of the U.S.

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*A Selective Analysis of Power Plant Operation on the Hudson River with Emphasis on the Bowline Point Generating Station, Oak Ridge National Laboratory, ORNL/TM-5877, June 1977.

Atomic Energy Commission's environmental statement concerning the Indian Point Generating Station, (2) the thermal regime of the Hudson River and (3) regional air quality. In addition, the present final environmental statement* has been developed to incorporate the major findings of the study undertaken by the Oak Ridge National Laboratory and to present the District's analysis of other related impacts. The full text of the consent decree is included in Appendix B.**

1.08 A related legal action concerns the Roseton Generating Station Units No. 1 and No. 2 located in the Village of Roseton, Town of Newburgh, Orange County, New York. The station comprises two fossil-fueled units, with a nominal combined capacity of 1,200 megawatts, constructed by Central Hudson Gas and Electric Corporation (Central Hudson) and owned jointly by Central Hudson, Con Edison and Niagara Mohawk Power Corporation (Niagara Mohawk). On 29 December 1972, the Hudson River Fishermen's Association and other plaintiffs filed a complaint in U.S. District Court, Southern District of New York, alleging that the withdrawal of water by the Roseton Generating Station for condenser cooling purposes would result in serious damage to the environment, including the entrainment of substantial numbers of striped bass eggs, larvae and juveniles. The plaintiffs alleged further that the District had wrongfully issued a Department of the Army permit under Section 10 of the River and Harbor Act of 1899, authorizing Central Hudson on 13 March 1970 (with later amendment of the permit on 20 December 1971) to construct within the navigable waters of the Hudson River certain facilities related to the Roseton Generating Station, in that issuance of this permit had not been preceded by the submission of an environmental impact statement in accordance with the requirements of the National Environmental Policy Act of 1969.

1.09 On 25 July 1974, the Court sanctioned a consent decree entered by consent of the Hudson River Fishermen's Association and the District, together with Central Hudson, Con Edison and Niagara Mohawk. Under the terms of the decree, the District is required to review and evaluate the construction and operation of the Roseton Generating Station and to determine whether suspension, modification or revocation of the permit may be necessary for the protection of the fish and wildlife resources of the Hudson River. The study and

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*This document is derived, in part, from a draft environmental statement submitted to the Council on Environmental Quality on 23 August 1974, and from an uncirculated final environmental statement prepared by the District in January 1976.

**Appendix A is reserved for comments to this draft environmental statement.

evaluation are to be based on: 1) information and data developed by the District in preparing the environmental impact statement relating to the Bowline Point Generating Station 2) information and data pertinent to Con Edison's application to the District for a permit authorizing dredge and fill work connected with the proposed pumped storage facility at Cornwall, New York, and 3) the review and comments on the draft statement by the plaintiffs in the Roseton action, the Department of the Interior, the National Marine Fisheries Service, the Environmental Protection Agency, the regulatory staff of the Atomic Energy Commission (now the Nuclear Regulatory Commission), the New York State Department of Environmental Conservation and other persons or governmental agencies. The full text of this second consent decree is included in Appendix B.

BOWLINE POINT GENERATING STATION*

1.10 The Bowline Point Generating Station is sited on the west bank of the Hudson River at (River) Mile Point 38 north of the Battery in Manhattan, New York City. A view of the Bowline Point Generating Station from the Hudson River is given in Figure 1-1 and a plot plan of the station in Figure 1-2. The site extends over 245 acres and encompasses the 53-acre Bowline Pond. Prominent features of the station include the central power plant complex, a fuel oil storage facility, a marine terminal and a recreational facility located immediately to the east of Bowline Pond and north of the pond inlet.

Power Generating Equipment

1.11 The Bowline Point Generating Station comprises two oil-fueled steam electric generating units of conventional modern design, each rated at a nominal 600 megawatts. Each unit consists of a steam generator, a turbine generator and associated auxiliary and control equipment.

1.12 Combustion Engineering, Inc. supplied the steam generator for Unit 1, and the Babcock and Wilcox Company supplied the steam generator for Unit 2. Both turbine generators were supplied by the

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*Material in this section is derived from a description of the Bowline Point project (Orange and Rockland, March 1971) prepared for Orange and Rockland by Bechtel Associates. Updated information based on operating experience has been provided by Orange and Rockland. Supplementary information on the Bowline Point Generating Station and certain other facilities sited along the Hudson River was gathered during a visit of the facilities on 3 and 4 November 1976 and subsequent requests for additional information from the operators of the generating stations on the Hudson River.

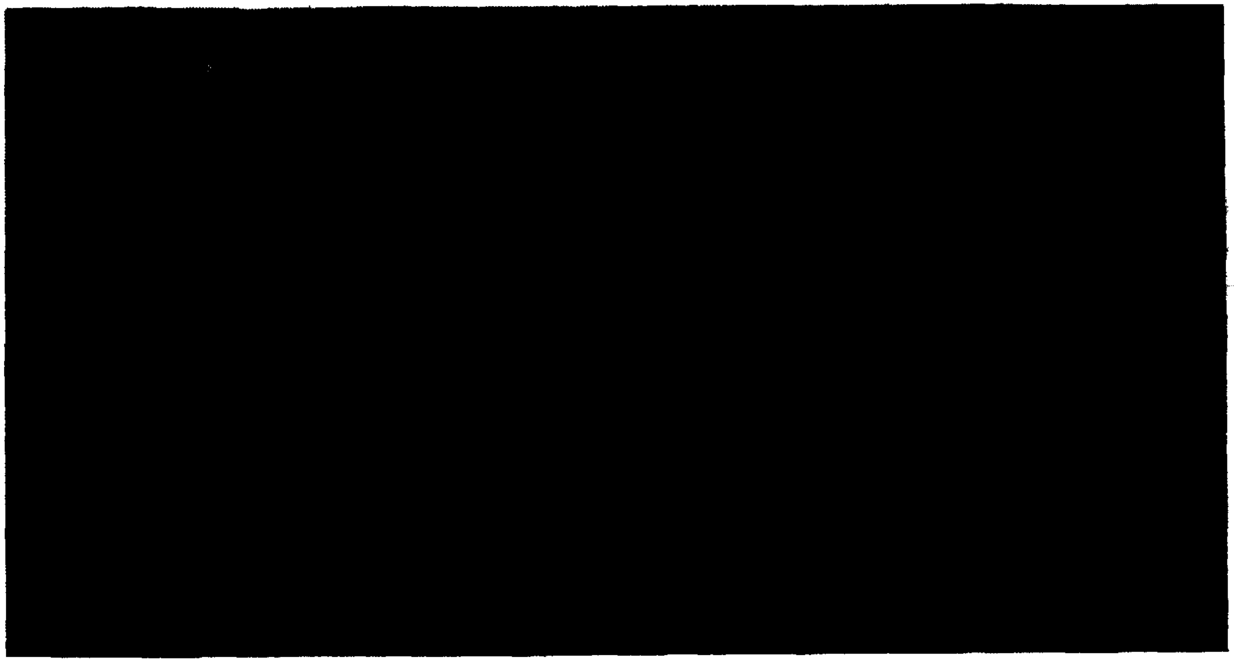
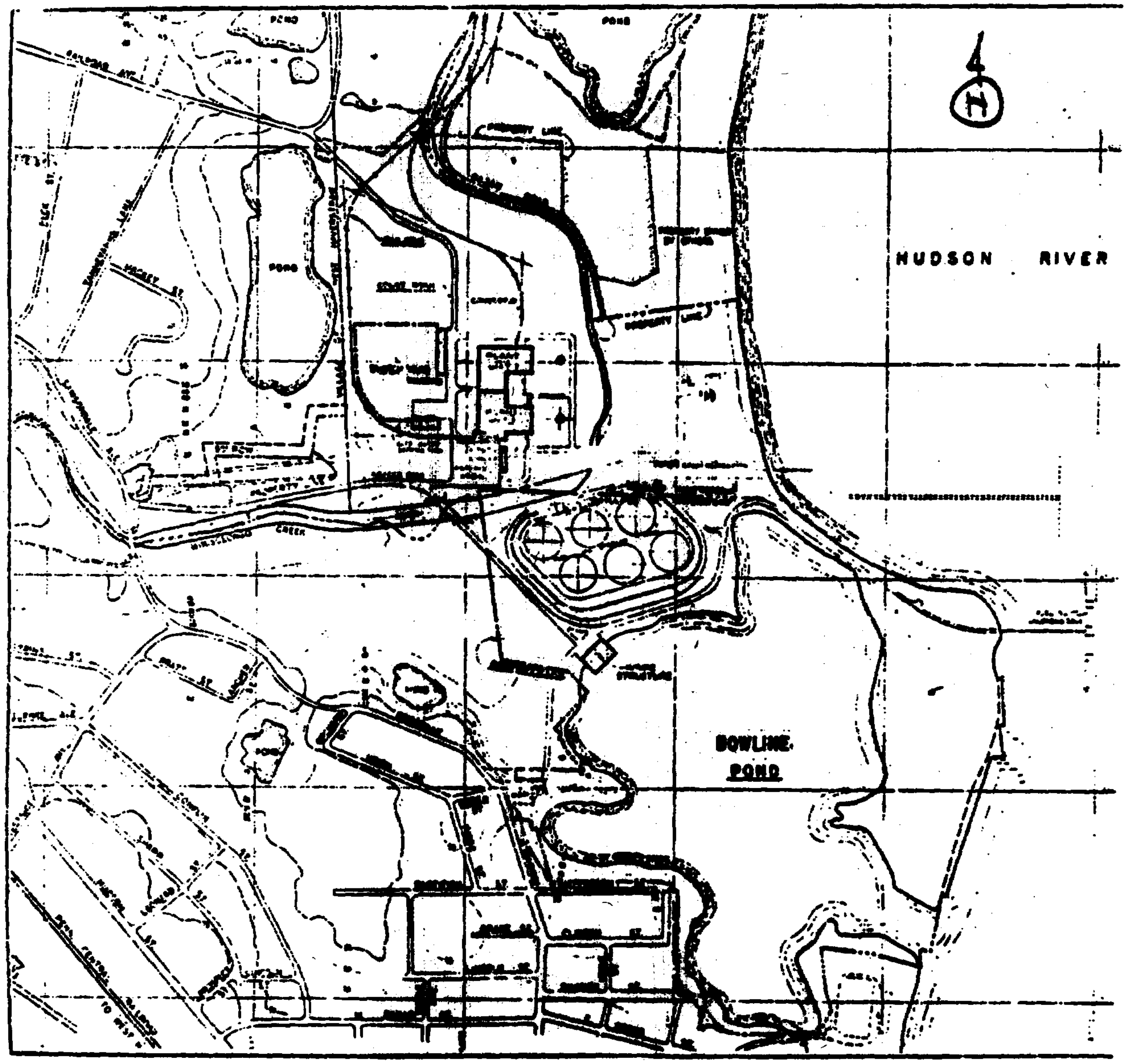


FIGURE 1-1

THE BOWLINE POINT GENERATING STATION VIEWED FROM THE HUDSON RIVER



Source: Orange and Rockland, March 1971.

FIGURE 1-2

PLOT PLAN OF THE BOWLINE POINT GENERATING STATION

General Electric Company. Although the units differ in certain technical details, they are practically identical in all aspects relating to their interaction with the environment and are treated accordingly throughout this analysis.

1.13 The generating units operate a steam cycle with a single stage of reheat of the main steam and six stages of feedwater heating. Each steam generator includes a water cooled furnace, superheater, reheater, economiser, regenerative air heaters, soot blowing equipment, burner and ignition control assemblies, and integrated control system. The steam generators are designed to deliver at maximum continuous rating 4.20 million pounds of steam per hour at 1005°F at the superheater outlet and 3.79 million pounds of steam per hours at 1005° at the reheater outlet. The maximum guaranteed superheater outlet pressure is 2600 pounds per square inch guage. The thermal efficiency of the steam generator exceeds 89 percent.

1.14 Each turbine generator has a nominal nameplate capacity of 555 megawatts at nominal throttle steam conditions of 2,400 pounds per square inch guage and 1000°F, with reheat to 1000°F. The turbine generators are tandem compound, four flow condensing reheat units, designed to operate at 3,600 revolutions per minute.

1.15 Operation of plant auxiliary equipment such as pumps, fans and impellers entails the consumption of electrical energy at a rate of approximately 21 megawatts. The net station capability (power delivered to the transmission line leaving the station) under normal, full power operating conditions is 1,201 megawatts. The overall thermal efficiency of the plant is 35.6 percent, corresponding to a net plant heat rate of 9,600 BTU per kilowatt-hour.

Fuel Supply

1.16 The Bowline Point generating units are designed to burn fuel oil and natural gas as an alternative fuel. With substantial modifications, the units could be converted to burn coal. Facilities would have to be provided to receive, handle and pulverize the coal feed and structural changes would have to be made to handle the increased ash load. Equipment would have to retrofitted to control the emission of airborne particulate matter. Since the plant has not been designed or constructed to burn coal, it is not subject to prohibition from burning petroleum products by the Federal Energy Administration pursuant to Section 2 of the Energy Supply and Environmental Coordination Act of 1974 (P.L. 93-319 as amended by P.L. 94-163).

1.17 The station currently burns #6 fuel oil supplied under a long-term agreement by New England Petroleum Corporation, Amerada-Hess Corporation and Asiatic Petroleum Corporation. In accordance with the conditions of the supply contract, the sulfur content of the fuel oil is limited to 0.37 percent by weight or less. The ash content of the fuel oil is 0.02 percent and its average heating value is 5.77 million BTU per barrel.

1.18 The consumption rate of fuel oil with both units operating at full power is 1,897 barrels per hour. This corresponds to a maximum daily (24 hours) consumption rate of approximately 30,000 barrels and an annual consumption of 10 million barrels at an overall plant load factor of 0.66. The aggregate storage capacity provided on site is 810,000 barrels, which is an adequate reserve to operate both units at full power for 17 days. In normal circumstances, the reserve is replenished every 1.5 days by supply barges of 55,000 barrel capacity.

Cooling System

1.19 The Bowline Point Station currently operates with a once-through or open cycle condenser cooling system. While either one of the generating units is in operation, cooling water is withdrawn continuously from Bowline Pond, circulated through the main condenser and discharged to the Hudson River through submerged diffusers.

this is not correct

1.20 Each of the two plant condensers is designed to reject heat at the rate of 2.79 billion BTU per hour at a flow rate of 375,000 gallons per minute and a temperature rise of 15F. In actual practice a flow rate of 316,000 gallons per minute is maintained through each condenser and the average temperature rise is 13.5F at full power operation. The corresponding heat rejection rate is 2.14 billion BTU per hour from each unit.

one motor — no?

1.21 A battery of six pumps, each rated at 128,000 gallons per minute and equipped with a 1,500-horsepower motor, supplies cooling water to the plant condensers. The pumps are arranged in two independent sets of three pumps, one set serving each of the generating units. Under normal conditions, two pumps per set are kept running while the corresponding unit is in operation. The third pump would be on standby or undergoing maintenance. The pumps are housed in the intake structure on Bowline Pond.

1.22 Cooling water is pumped a distance of approximately 1,600 feet through two underground 126-inch diameter pipes to the condensers located in the main plant. The heated water leaves the system through two underground 126-inch pipes that terminate in diffusers approximately 1,300 feet offshore on the river bottom. The overall pipe length from the condensers to the diffusers is about 2,850 feet. The underwater portions of the discharge line are supported on steel pile bents driven into glacial till approximately

130 feet below the surface of the river to ensure stability of the line with respect to both alignment and elevation.

1.23 Provisions have been made to recirculate a portion of the cooling water discharge back to Bowline Pond as a means of preventing ice blockage of the intake in severe weather.

Power Buildings and Facilities

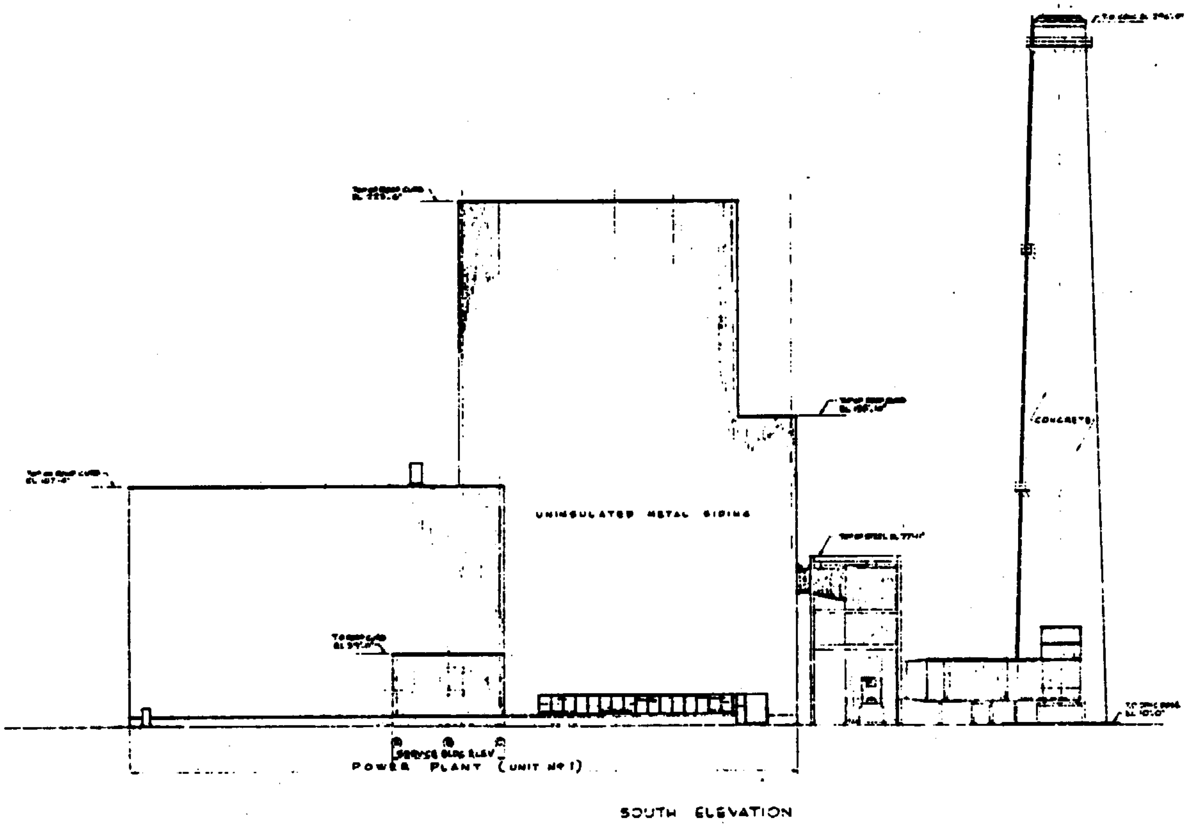
1.24 The main plant buildings house the steam generators, steam turbines, electric generators and associated equipment. The south and east (riverfront) elevations of the buildings are shown in Figures 1-3 and 1.4. The roofs of the two steam generator sections of the plant and the roof of the turbine-generator section are, respectively, 214 feet and 97 feet above plant grade. The main building is 460 feet long and 273 feet wide. The building exterior is clad with ribbed metal siding, permanently finished in medium brown.

1.25 Two concrete stacks, measuring 287.5 feet in height and 37 feet in base diameter, are located 110.5 feet east of the power building, with a center-to-center separation of 286 feet. Aircraft warning lights are present on each of the stacks.

1.26 A two-story service building immediately south of the main plant provides space and facilities for administrative, clerical and laboratory support functions. The structure serves both Units 1 and 2 and is connected to the main plant building by sidewalks at ground level and an enclosed bridge on the second floor. The service building is 115 feet long, 46 feet wide and 29 feet high.

1.27 A warehouse serves as a central storage area for equipment, materials and supplies. The warehouse is 220 feet long, 50 feet wide, 16 feet high and is located approximately 127 feet to the west of the main plant, immediately adjacent to the switchyard. A building, about 200 feet south of the warehouse contains shop and other maintenance facilities. The shop building is 140 feet long, 50 feet wide and 16 feet high.

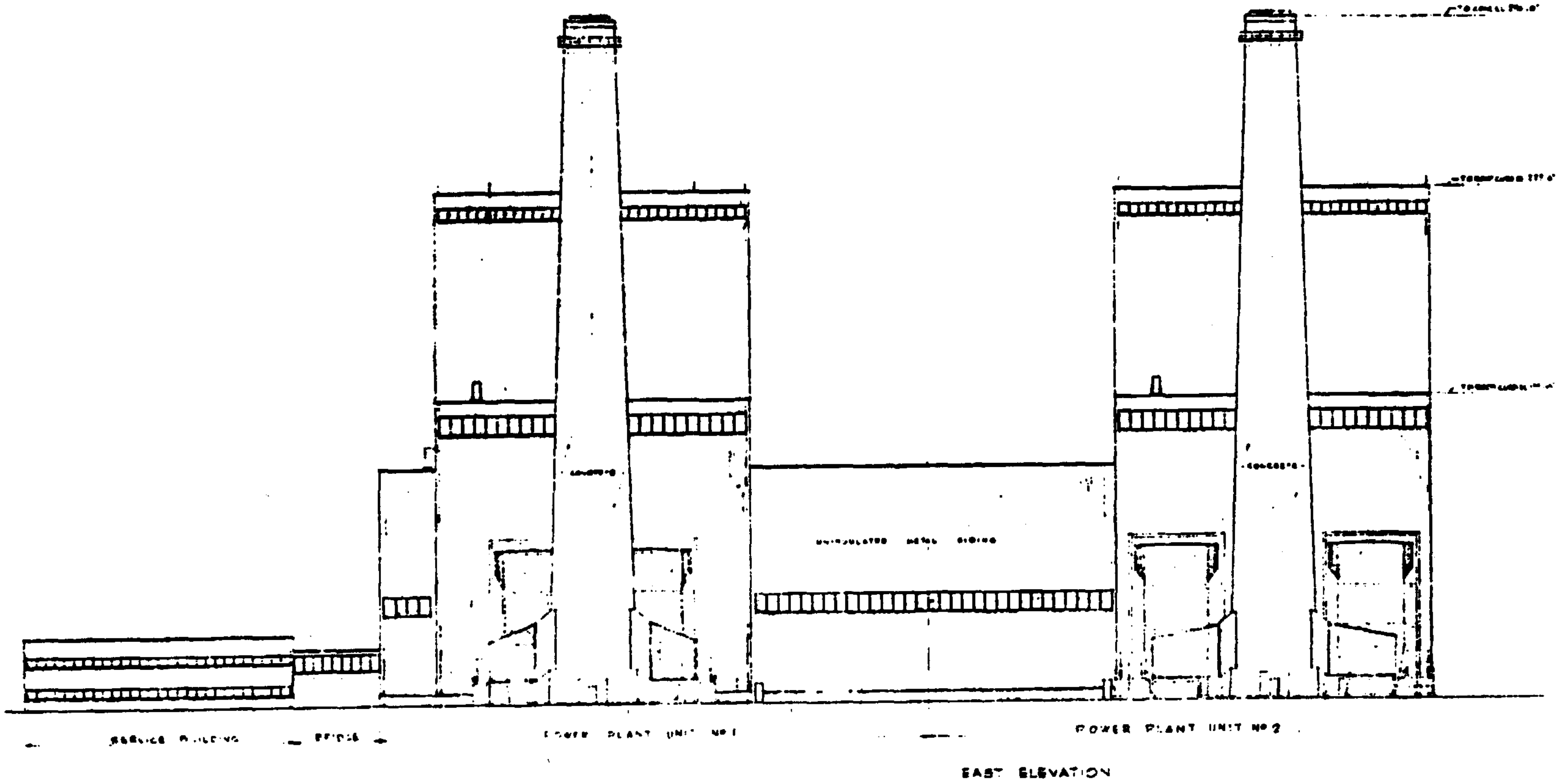
1.28 The station switchyard accommodates the main transformers, towers, electrical buses, breakers and related equipment necessary to deliver the electrical power generated by Units 1 and 2 to Orange and Rockland's transmission network. The switchhouse, consisting of meter and relay rooms, is located in the south end of the warehouse building.



Source: Orange and Rockland, March 1971.

FIGURE 1-3

BOWLINE POINT GENERATING STATION--SOUTH ELEVATION



Source: Orange and Rockland, March 1971.

FIGURE 1-4
BOWLINE POINT GENERATING STATION--EAST ELEVATION

Fuel Oil Storage Facility

1.29 Six fuel oil tanks, each of 145,000-barrel capacity (135,000-barrel operating capacity), are located within an 8-acre tract surrounded by a berm immediately north of Bowline Pond and adjacent to the south bank of Minisceongo Creek. Sufficient fuel oil can be stored to allow both Units 1 and 2 to operate at full power for a period of approximately 17 days, ensuring a continuity of power generation in the event of a temporary disruption in fuel oil delivery. A fuel oil pumphouse, measuring 50 feet in length and 38 feet in width, is recessed into the berm on the north side and houses pumps to transfer fuel oil to the power plant. Also housed in the pump structure is a portion of the fire protection system as well as a surface water drainage sump designed to minimize the discharge of oily waters into Minisceongo Creek and the Hudson River.

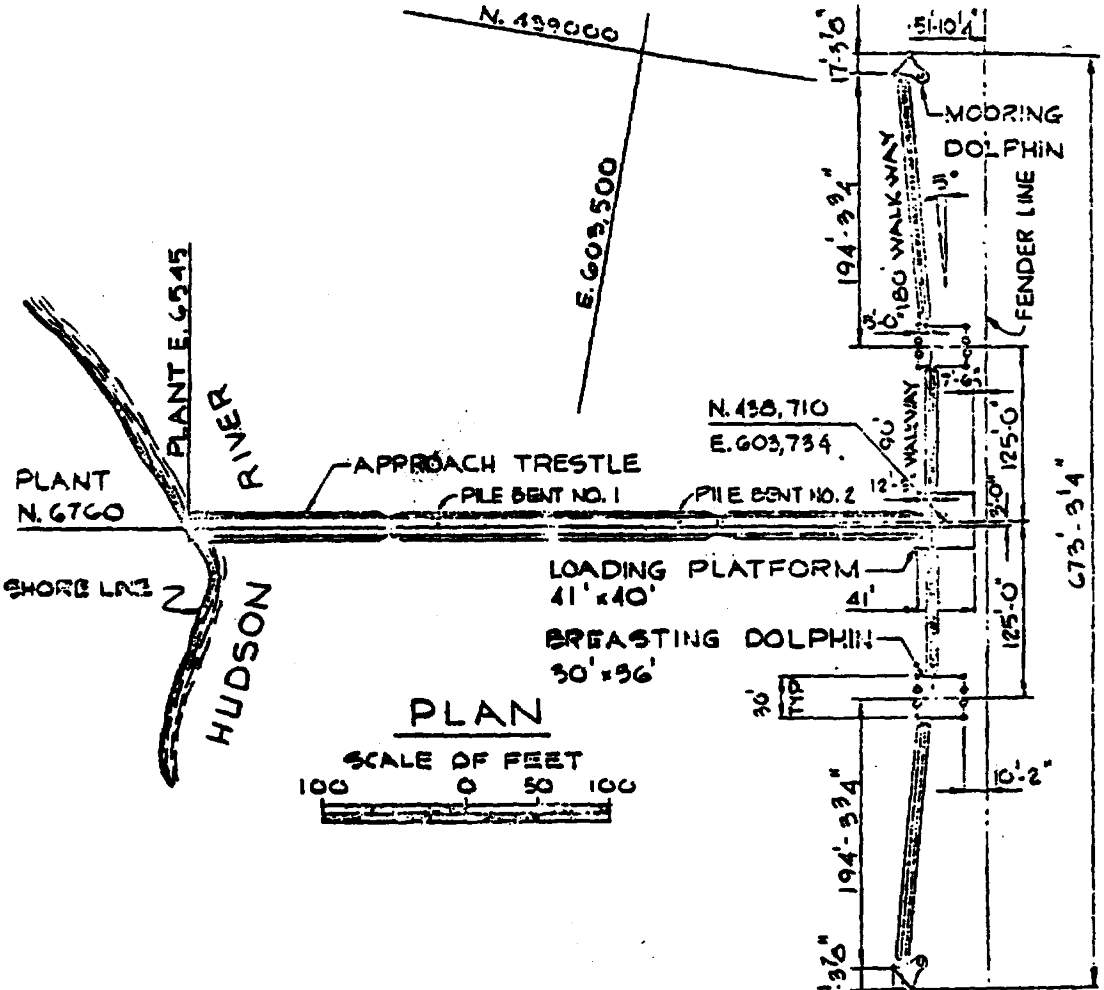
1.30 The berm serves the dual purpose of providing containment in the event of oil leakage from any of the storage tanks and partially screening the tanks from public view. The oil tanks are cylindrical with slightly domed tops; each tank is 180 feet in diameter and 32 feet in overall height. The height of the berm varies between 10 and 28 feet. Grass has been planted on the earthern slopes of the berm.

Marine Terminal

1.31 The marine terminal is an oil receiving facility designed to accommodate barges and tankers delivering fuel oil to the plant. While tankers of up to 50,000 deadweight tons could be docked at the facility, the present depth contours of the Hudson River limit access to the terminal to barges of 100,000-barrel capacity or less.

1.32 A trestle connects the fuel oil unloading pier to the shoreline. Extending north and south from the oil unloading pier are personnel walkways to the breasting and mooring dolphins. All of these structures are supported by piles anchored in the underlying rock stratum. The trestle piers, walkways and dolphins are constructed entirely of steel members. The supporting pile bents are widely spaced and provide a clearance beneath the trestle of approximately 15 feet at mean low water. Articulated metal arms are used for unloading vessels. A steam line to the unloading pier provides the heat necessary to maintain the fuel oil at approximately 100F to allow it to flow readily.

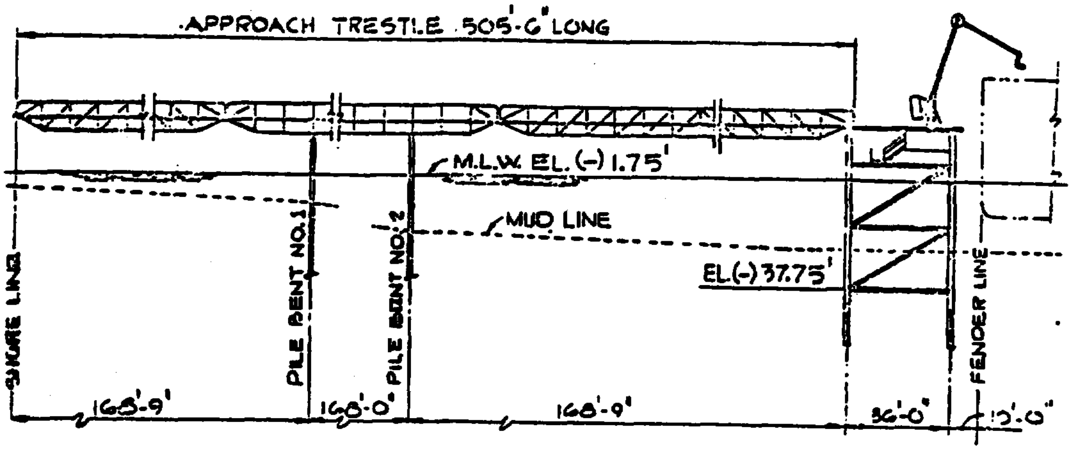
1.33 Further details of the fuel oil unloading terminal are given in Figures 1-5 and 1-6. As indicated, the dock structure is approximately 675 feet long and is oriented along a north-south line parallel to river flow, 500 feet from the west bank of the Hudson



Source: Application to the District by Orange and Rockland.

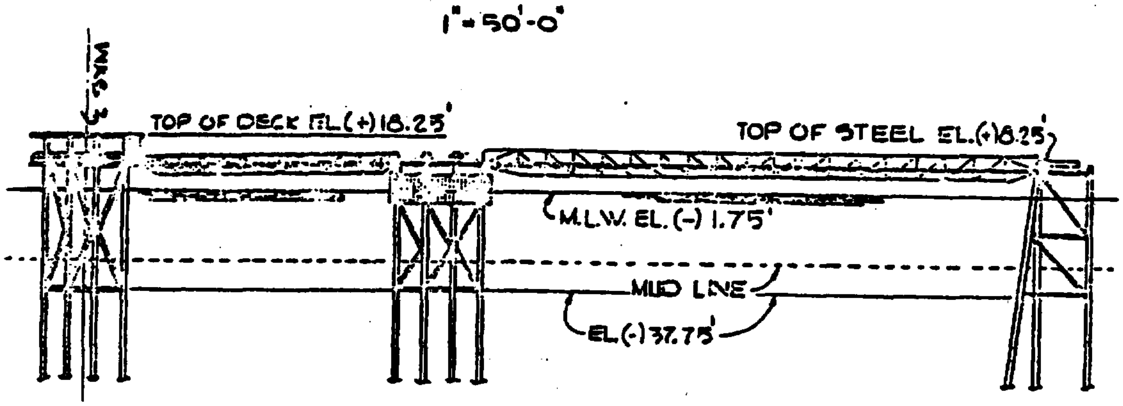
FIGURE 1-5

FUEL OIL UNLOADING PIER-PLAN



SIDE ELEVATION

1" = 50'-0"



FRONT ELEVATION

1" = 50'-0"

Source: Application to the District by Orange and Rockland.

FIGURE 1-6

FUEL OIL UNLOADING PIER-ELEVATIONS

River. The transfer pier is centered at about latitude 41°12' North, longitude 73°57' West (New Yrok State coordinates 438710N and 603734E).

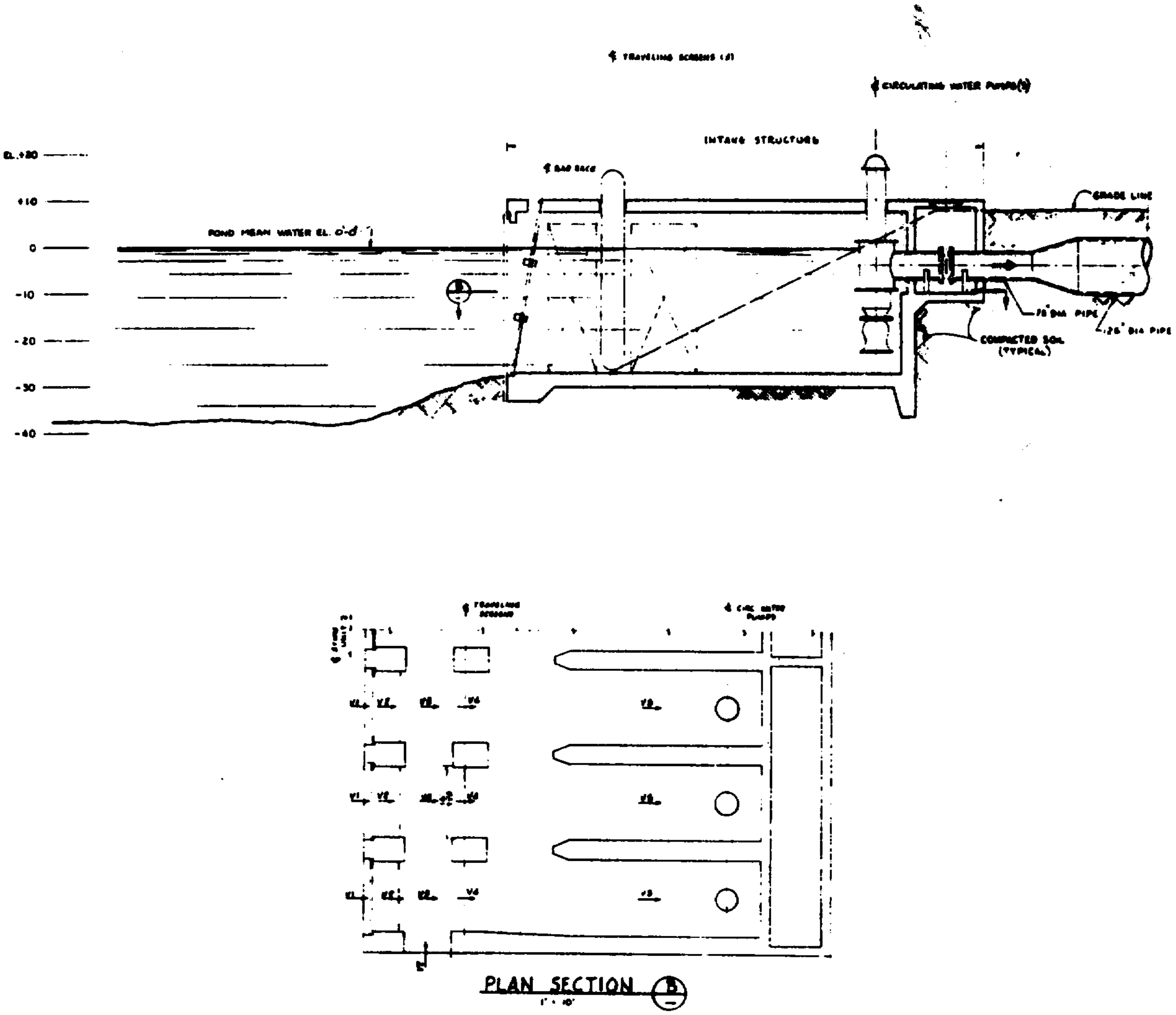
Intake Structure

1.34 The cooling water intake structure is located on the northwest shore of Bowline Pond, directly across the pond from the inlet channel to the Hudson River. The major components of the intake system are the intake ports, common plenum, traveling screens, pump bays and circulating water pumps.

1.35 Pertinent engineering details of the intake structure are given in Figure 1-7. As indicated in the schematic, each of the six circulating pumps is housed in a separate bay. A common plenum is provided across the entire width of the structure to allow water from any intake port to enter any pump bay. Water enters the structure through a total of eight ports, six across the face of the structure and one on each side. The water first passes through the bar racks located behind the intake ports. Large fish and debris are prevented from entering the structure by 1/2 x 3-inch vertical bars with a 3-inch separation between bars.

1.36 Traveling screens are located approximately 16 feet behind the bar racks. The screens are of standard design adopted widely throughout the utility industry and consist of screen panels or "baskets" attached to an endless chain belt that revolves between two sprockets in a vertical plane. The screen mesh or size of the openings is three-eights inch square. While the circulating water pumps are in operation, the traveling screens are moved upward periodically and impinged fish and debris are lifted above the main floor of the intake building into a cleaning chamber. Water drawn from the pond is sprayed onto the screens through a row of nozzles. Two spray systems, a high and a low pressure system, operate at a pressure of 60 and 20 pounds per square inch, respectively. Waste waters from the backwash operation are sluiced to a tank with an outlet channel to Bowline Pond. The collection and return system provides an opportunity for fish that survive impingement and backwash to return to Bowline Pond.

1.37 Operating experience has shown that the frequency at which the screens must be moved and backwashed varies throughout the year. During periods of low debris loading of the river and low fish impingement, the screens are moved once every four hours. At other times, the screens run continuously. A mechanism drives the screens automatically on a signal of excessive water level differences across the face of the screen. The operation can also be controlled manually.



Source: Orange and Rockland, March 1971.

FIGURE 1-7

DETAILS OF THE COOLING WATER INTAKE STRUCTURE

1.38 Flow velocities at various points in the intake structure have been computed on the basis of estimated flow rates and cross sectional areas. The points are identified as V1 through V5 in Figure 1-7, and flow velocities under a number of conditions are given in Table 1-1. Values of velocity are given for mean water, mean low water and low low water elevations in Bowline Pond. Under normal conditions of full power operation (both units operating and 2 pumps running per generating unit), the approach velocity to the bar rack varies between 0.45 and 0.53 feet per second, depending on the water level in the pond. The corresponding values through the bar racks are 0.59 and 0.66 feet per second. The approach velocity to the screens varies between 0.54 and 0.64 feet per second and the velocity through the screens between 1.06 and 1.25 feet per second.

1.39 Water enters Bowline Pond from the Hudson River through an inlet channel that has been widened and deepened to augment flow into and out of the pond. Estimates of the flow velocities induced in the channel by the withdrawal of cooling water from the pond are given in Table 1-2. The velocities apply when both units are operating under conditions of mean water, mean low water and low low water elevations. With two pumps running per unit and a total withdrawal of 632,000 gallons per minute from Bowline Pond, velocities ranging between 0.44 and 0.60 feet per second are induced at the inlet; the range corresponds to extremes in water elevation. Under conditions of low low water and all 6 pumps operating, the induced velocity would reach a maximum of 0.74 feet per second.

1.40 The net velocity at the Pond inlet is the resultant of the velocity induced by the withdrawal of water and the flow velocity associated with tidal action. The mean tidal range of the Hudson River in the vicinity of Bowline Point is 2.9 feet (U.S. Department of Commerce, 1972), and the maximum flow velocity in the inlet channel corresponding to this tidal range is estimated to be 0.2 feet per second (Orange and Rockland, March 1971). Maximum flow occurs midway between the times of ebb slack and flood slack, with flow directed into the pond during flood tide and out of the pond during ebb tide. Accordingly, a value of 0.2 feet per second should be, respectively, added to and subtracted from the values given in Table 1-2 to obtain the net velocity in the channel during periods of inflow and outflow.

Discharge Diffusers

1.41 Discharge pipes from the condenser extend approximately 1,000 feeet due east into the Hudson River and terminate in two diffusers mounted at right angles to the pipes. The diffusers roughly parallel the fuel oil unloading dock and are slightly to the north and shoreward of the facility.

TABLE 1-1

FLOW VELOCITIES IN THE INTAKE STRUCTURE

WATER ELEVATIONS(1)	PUMPS OPERATING AND FLOW IN GALLONS PER MINUTE PER UNIT(2)	FLOW VELOCITIES IN FEET PER SECOND(3)				
		V1	V2	V3	V4	V5
Mean Water,	3 - 384,000	0.55	0.72	0.66	1.29	0.65
Elevation 0.00	2 - 316,000	0.45	0.59	0.54	1.06	0.79
	1 - 185,000	0.27	0.35	0.34	0.67	0.93
	2 - 257,000 Throttled Condition	0.37	0.48	0.44	0.86	0.64
Mean Low Water,	3 - 384,000	0.59	0.77	0.70	1.38	0.69
Elevation - 1.75	2 - 316,000	0.48	0.63	0.58	1.13	0.85
	1 - 185,000	0.29	0.37	0.36	0.72	1.00
	2 - 257,000 Throttled Condition	0.39	0.51	0.47	0.92	0.69
Low Low Water,	3 - 384,000	0.65	0.81	0.77	1.53	0.76
Elevation - 4.00	2 - 316,000	0.53	0.66	0.64	1.25	0.93
	1 - 185,000	0.31	0.34	0.40	0.79	1.10
	2 - 257,000 Throttled Condition	0.43	0.54	0.52	1.02	0.76

Source: Orange and Rockland, March 1971.

(1) Elevations refer to water level in Bowline Pond; see Figure 1-7.

(2) Velocity values apply when both power units are in operation; the values would be less than those indicated when only one of the units is in operation.

(3) The points at which the velocity values apply are identified in Figure 1-7 and are as follows:

V1 - average approach velocities to the bar racks
V2 - velocity through the bar racks
V3 - approach velocity to the screens
V4 - velocity through the screens
V5 - approach velocity to the pumps

TABLE 1-2

FLOW VELOCITIES IN THE BOWLINE POINT INLET CHANNEL

WATER ELEVATIONS (1)	PUMPS OPERATING PER UNIT AND TOTAL FLOW (2) IN GALLONS PER MINUTE	FLOW VELOCITY (2) IN FEET PER SECOND
Mean Water,	3 - 768,000	0.54
Elevation 0.00	2 - 632,000	0.44
	1 - 370,000	0.26
	2 - 514,000 Throttled condition	0.36
Mean Low Water,	3 - 768,000	0.61
Elevation - 1.75	2 - 632,000	0.50
	1 - 370,000	0.29
	2 - 514,000 Throttled condition	0.41
Low Low Water,	3 - 768,000	0.74
Elevation - 4.00	2 - 632,000	0.60
	1 - 370,000	0.35
	2 - 514,000 Throttled condition	0.49

Source: Orange and Rockland, March 1971.

(1)Elevations refer to water level in Bowline Pond; see Figure 1-7.

(2)Total flows and velocities apply when both units are operating; values are approximately one-half those indicated when only one unit is operating.

1.42 Each diffuser consists of a 220-foot section of 126-inch diameter pipe with eight discharge nozzles. The nozzles are 3 feet in diameter, spaced 25 feet on centers and inclined 5 degrees from the horizontal to reduce scouring of the river bottom. Heated water leaves the nozzles with a velocity of approximately 15 feet per second. The jets induce turbulence and mixing with ambient waters, producing a rapid reduction in the temperature of the effluent stream. Details of the dischage piping and diffusers are given in Figure 1-8.

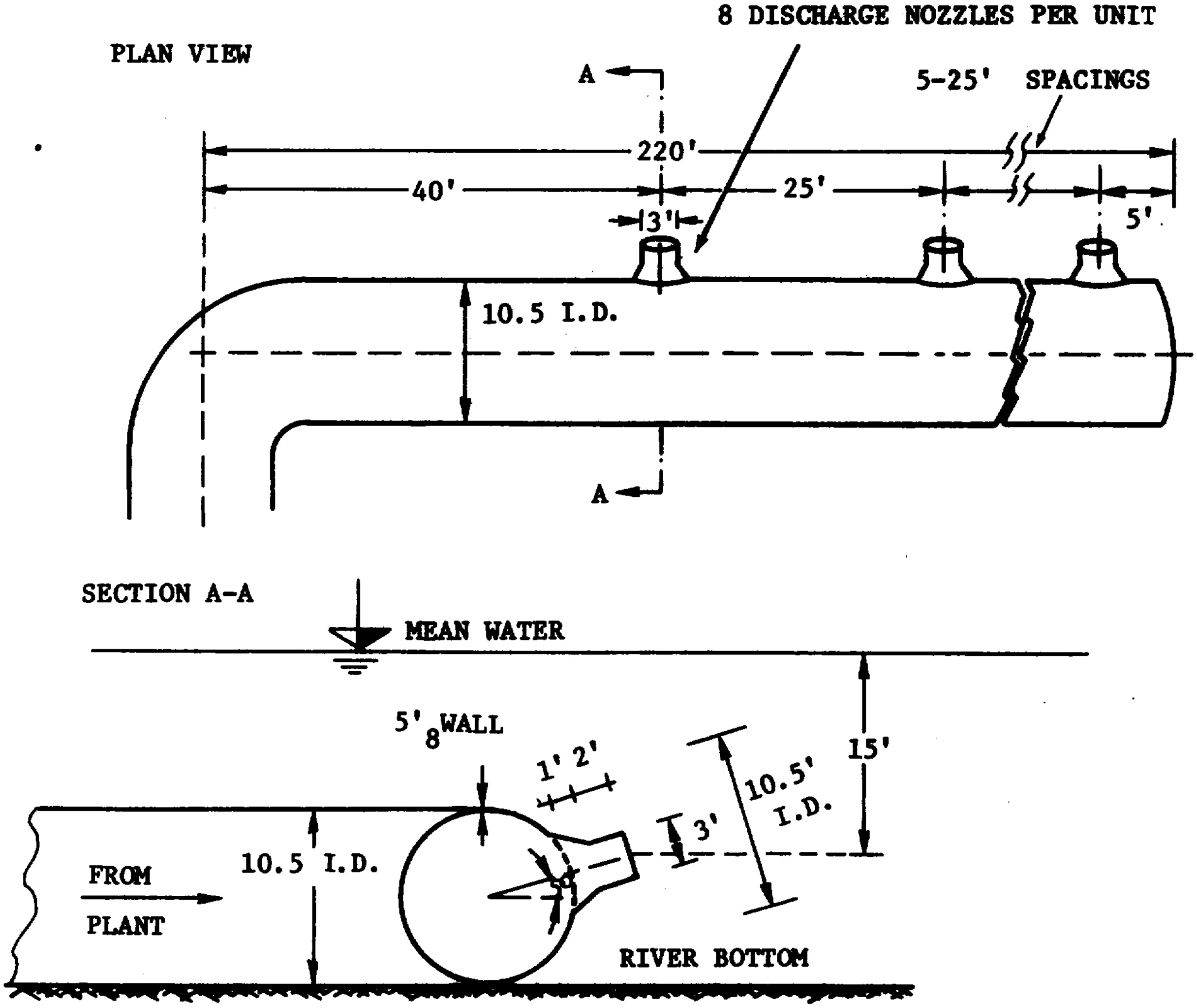
Recreational Facility

1.43 Orange and Rockland and Con Edison deeded to the town of Haverstraw 10.8 acres of land as the Bowline Point site for the development of a public recreational facility. The same companies contributed a total of $750,000 towards construction costs of the amenities and the town expended an additional $300,000 (Rotella, 1976). The facility, which is operated by the Town of Haverstraw, now includes a swimming pool and dressing rooms, picnic areas, basketball and tennis courts, and a pavilion. The park has been open to the public since late summer of 1976. An admission fee is charged for each visit to the center; daily and seasonal rates are available. Access by road to the facility is unrestricted.

Site Preparation

1.44 Site preparation at Bowline Point prior to construction of the power plant entailed the removal of existing garbage, draining and filling of certain portions of the site, pest and rodent control measures, the relocation of a portion of Minisceongo Creek, and dredging of the inlet to Bowline Point. Parts of the site had been used as a dump for discarded automobiles, household appliances and other garbage and for casual trash disposal (Orange and Rockland, March 1971). The garbage fill, up to 10 feet in depth in certain sections, was removed from all areas now occupied by major structures and replaced by clean fill dirt. In other areas of the site the garbage was covered with clean fill and compacted.

1.45 Low lying portions of the property were occupied by stagnant ponds and poorly drained areas. A drainage system consisting of surface drainage channels and underground storm sewers was constructed to provide drainage to Minesceongo Creek or Bowline Pond. Where adequate drainage existed, growths of scrub brush and larger trees had become established. Programs of vegetation clearing and rodent and insect extermination were carried out concurrently with excavation and site grading (Orange and Rockland, March 1971).



Source: Orange and Rockland, March 1971

FIGURE 1-8

DETAILS OF DISCHARGE DIFFUSERS AT THE
BOWLINE POINT GENERATING STATION

1.46 The portion of Minisceongo Creek to the east of the present power plant building traversed a low lying part of the site, and the creek channel became ill defined in the area. To prevent flooding and improve drainage, a diversion channel was cut between the existing creek bed and the Hudson River. The channel is subject to tidal inflow; excess water flows northward off the property along the remainder of the original water course and ultimately is discharged to the river.

1.47 The existing inlet channel between Bowline Pond and the Hudson River was shallow and permitted limited tidal flow between the pond and the Hudson River. The channel was dredged to a depth of 16 feet and a top width of 219 feet to increase tidal flow into and out of the pond. Approximately 49,000 cubic yards of material were removed in dredging the inlet channel; the dredged material was used for onland fill on the property. An additional 51,000 cubic yards of material were dredged in laying the subaqueous cooling water lines and discharge diffusers. The material was used to fill in an existing pond to the north of the power plant site.

1.48 The primary access road to the plant extends from an intersection at Samsondale Avenue immediately north of the bridge over Miniscenongo Creek to the plant parking lot. Intraplant roads, closed to public traffic, extend northward from the parking lot, providing access around the power plant building, shop and warehouse. Immediately to the west of the parking lot, a branch of the access road extends southeast to the intake structure and then along the north shore of Bowline Point to the recreational facility and marine terminal.

1.49 The intersection at Samsondale Avenue was planned to minimize interference with local traffic and accomodate the anticipated high volume of traffic related to the use of the recreational facility during summer months. Samsondale Avenue has been widened to allow through traffic to bypass vehicles turning onto the access road. Additionally, vehicles from the plant can enter Samsondale Avenue safely and without undue delay. The intersection was designed to obviate traffic lights.

1.50 A through girder, clear span bridge provides a crossing over Minisceongo Creek. The bridge consists of two 15-foot traffic lanes and walkways on either side. The bridge is designed to carry a heavy crane which may be required once in several years for maintenance work at the intake structure and, therefore, provides ample capacity for the heaviest automobile and truck traffic. The clear span across the creek ensures that the bridge will be safe during periods of heavy runoffs.

1.51 McKenzie Avenue in the Village of Haverstraw (the extension of Warren Avenue shown in Figure 1-1) was extended to intersect the site access road near the plant intake structure, providing an alternative route to the recreational facility. Rerouting of the original McKenzie Avenue required the acquisition of the right-of-way presently following the lines shown in Figure 1-2.

1.52 Additional access to the site during construction was provided by an extension of Railroad Avenue. The road has since been closed to plant traffic, except for occasional maintenance and delivery use. A railroad spur leading from the Conrail Railroad in the Town of Haverstraw was constructed on a right-of-way purchased by Orange and Rockland. This spur was used mainly during construction of the plant; train passage is currently infrequent and limited to occasional delivery.

Transmission Lines

1.53 Connecting the Bowline Point station to existing power distribution networks serving the Orange and Rockland and New York Power Pool systems required the construction of approximately 3.4 miles of underground 345-kilovolt transmission line circuits. The transmission lines from the plant are routed to Orange and Rockland's West Haverstraw substation located 1.2 miles west of Samsondale Avenue. Underground construction was selected to eliminate the visual impact of overhead transmission lines in residential areas.

Current Project Status

1.54 Construction of the first unit at the Bowline Point Generating Station began in the Spring of 1969. Unit No. 1 entered limited commercial service on 8 September 1972 and full commercial service on 21 October 1972. Unit No. 2 entered commercial service on 1 May 1974.

1.55 All site preparation, landscaping and other site closeout work is complete. Construction work related to the generating units is complete. The marine terminal has been ready to receive oil since 5 April 1972. Dredging operations are complete. The recreational facility, first opened to the public late in the 1976 season, is now operational.

1.56 Table 1-3 lists the applications filed by Orange and Rockland and the major approvals that have been secured to date from various governmental entities, in connection with the Bowline Point Generating Station are listed in Table 1-3.

TABLE 1-3

APPLICATIONS AND APPROVALS RELATED TO THE BOWLINE POINT GENERATING STATION

AGENCY	PERMIT/APPROVAL	DATE OF ISSUANCE	REFERENCE/STATUS
U.S. Environmental Protection Agency, Region II	National Pollutant Discharge Elimination System Permit	31 Mar 75	Permit No. NY0008010 Exp. 30 Mar 1980
U.S. Army, Corps of Engineers, New York District	Dredging of inlet channel, installing of discharge piping and construction of a mooring facility (Section 10 Permit)	12 Jul 71	Permit No. 8304
U.S. Department of Transportation, Federal Aviation Administration	Permit to construct plant and stack	5 May 71	71-EA-203-OE
New York State Department of Environmental Conservation, formerly Department of Health	Construction permit for circulating water system	26 Oct 71	Form San. 2
	Operating permit for circulating water system	14 Nov 74	(NY0008010) 2SDOXW2000897
	Fuel oil facility rain water discharge	25 Apr 72	Permit dated 25 Apr 72
	Atmospheric discharge --permit to construct main boiler	7 Apr 71	Application No. C-700024
	Atmospheric discharge --permit to operate main boiler	7 Apr 71	Permit No. C-700024, Pending
	Atmospheric discharge --permit to construct auxiliary boiler	16 Aug 71	Letter advising no permit required (Letter No. W44-C71-0040)
	Atmospheric discharge --permit to construct auxiliary boiler	16 Aug 71	Letter advising no permit required (Letter No. W44-C71-0040

TABLE 1-3 (continued)
APPLICATIONS AND APPROVALS RELATED TO THE BOWLINE POINT GENERATING STATION

AGENCY	PERMIT/APPROVAL	DATE OF ISSUANCE	REFERENCE/STATUS
New York State Department of Environmental Conservation, formerly Water Resources Commission	Permit to construct intake structure and to dredge ponds	22 Jun 71	Intake Application No. 8-5-70 8-7-71*
		3 Nov 71	Discharge Application No. 8-5-70
	Permit to construct fuel oil unloading pier	26 Jun 70	Application No. 8-4-70
	Permit to install culverts in Minisceongo Creek for railroad siding	5 Aug 70	8-47-70
	Permit temporarily to relocate creek into Bowline Pond, construct bridge and improve creek channel	17 Sep 70	8-76-70
	Permit tp place fill in Bowline Pond	21 Sep 70	8-77-70
	Permit to place fill in pond north of Bowline Point	23 Dec 70	8-94-70
New York Public Service Commission	Approval of railroad crossings at Grassy Point Road and Gagan Road	28 Aug 70	Petition Case No. 25778
New York Commissioner of General Services	Purchase of underwater property for circulating water discharge and fuel oil unloading pier	27 Jan 72	Letter dated 27 Jan 72 filed under Liber 904 Pg. 794
Hudson River Valley Commission	Formal project review and approval	14 Apr 71	Letter dated 14 Apr 71
Rockland County Drainage Agency	Permit to install culverts in Minisceongo Creek for railroad siding	N. A.	N. A.

*No. 8-7-71 permits Orange and Rockland to remove more material.

TABLE 1-3 (concluded)

APPLICATIONS AND APPROVALS RELATED TO THE BOWLINE POINT GENERATING STATION

AGENY	PERMIT/APPROVAL	DATE OF ISSUANCE	REFERENCE/STATUS
Rockland County Highway Department	Approval of railroad crossing at Grassy Point Road	13 Aug 70	Letter
	Permit to install bridge over Minisceongo Creek for access to road to recreation area	8 Oct 70	Letter
Town of Haverstraw	Building permit, warehouse and shop	16 Sep 69	Permit No. 958.959
	Building permit; main plant, service building, switchyard and miscellaneous structures	5 Aug 71	Permit No. 661
	Approval of railroad crossing at Gagan Road	12 Aug 70	Letter
Village of Haverstraw	Building permit, circulating water intake structure	9 Mar 71	Permit No. 191
	Building permit, oil tanks and pier	9 Mar 71	Permit No. 192
Village of West Haverstraw	Approval of sanitary and waste disposal of sewage treatment plant	18 Mar 70	Letter

Project Review

1.57 Construction plans related to Bowline Point Unit 1 were reviewed by the Hudson River Valley Commission in 1971. In accordance with the provisions of the New York State legislative act that established the Commission in the mid-1960s, the Commission was required to review all proposed construction projects on the Hudson River, devoting attention to the visual impacts associated with each project, the impact on surrounding communities, the ecology of the river and broader environmental issues concerning the Hudson River basin.

Waterborne Discharges

1.58 The discharge of liquid effluents from the plant to the Hudson River and Minisceongo Creek is currently authorized by a National Pollutant Discharge Elimination System permit issued on 31 March 1975 by the U.S. Environmental Protection Agency in accordance with the provisions of the Federal Water Pollution Control Act Amendments of 1972 (33 U.S.C. 1251-1375).* Among other restrictions, the permit imposes limitations on the following: thermal discharges to the Hudson River (5.8 billion BTU per hour maximum heat rejection, 23oF maximum temperature increase 102F maximum temperature of discharge). The pH (range of 6.0 to 9.0 unless pH of the intake falls outside this range; then the pH of the discharge may not vary by more than 0.2 pH units from the pH of the intake) and content of free available chlorine in the discharge (0.2 milligrams per liter). Daily average velocity at the traveling screens (0.77 feet per second). Oil and grease content of discharges at Minisceongo Creek (15 milligrams per liter average, 20 milligrams per liter maximum).

Bring up to date by reference to application for State SPDES permit + continuation of "expired" permit issued by EPA

1.59 In accordance with the conditions of the permit, Orange and Rockland is required to adhere to the following schedule related to the retrofitting of a closed cycle cooling system:

(1) The permittee is required to complete an engineering report and submit the report to the New York Department of Environmental Conservation in accordance with New York State requirements by 1 January 1977.

State whether this was completed

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*For the sake of consistency, reference to the Federal Water Pollution Control Act Amendment is maintained in the Final Environmental Statement although the 1972 Statute has been amended and renamed the Clean Water Act (PL95-217) on 28 December 1977.

Done on time

(2) The permittee is required to complete final plans and specifications for the cooling system and submit these to the New York Department of Environmental Conservation by 1 June 1977.

(3) The permittee is required to submit reports detailing progress toward completion of the facilities by 1 March 1978, 1 December 1978, 1 September 1979, and 1 June 1980.

note this was stayed.

(4) The permittee is required to complete construction of the facilities by 1 April 1981.

(5) The permittee is required to attain operational levels of closed-cycle cooling by 1 July 1981.

1.60 On 30 July 1974, Orange and Rockland requested the U.S. Environmental Protection Agency, Region II to waive the requirement for closed cycle cooling, in accordance with the provisions of Section 316(a) of the Federal Water Pollution Control Act Amendments of 1972. Orange and Rockland prepared and submitted a demonstration document* in support of this request.

True?

1.61 As presently set forth, the terms of the National Pollutant Discharge Elimination System permit effectively constitute a denial of a waiver under Section 316(a) of the Federal Water Pollution Control Act Amendments. Concern over the continued operation of the Bowline Point Station with open cycle cooling centers on the damage to aquatic organism caused by the withdrawal of water from the Hudson River rather than the effects of the thermal discharge (Section 4). Accordingly, the requirement to install a closed cycle cooling system stems principally from Section 316(b) which provides that effluent limitations and standards of performance established in accordance with the statute "shall require that the location, design, construction and capacity of cooling water intake structures reflect the best technology available for minimizing environmental impact." The Environmental Protection Agency regards the term "capacity" to be synonymous with "throughout" or "flow rate" in the context of Section 316(b) (U.S. Environmental Protection Agency, 1976; 40 CFR 402);

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*Before the United States of America, Environmental Protection Agency, Region II, Re: Demonstration by Orange and Rockland Utilities, Inc. That operation of the Bowline Generating Station at Haverstraw, New York, with the Existing Once-Through Circulating Water System for Condenser Cooling, Will Assure the Protection and Propagation of a Balanced, Indigenous Population of Shellfish, Fish and Wildlife in and on the Hudson River in the Vicinity of Haverstraw and Elsewhere, Dated at Spring Valley, New York, 30 July 1974.

adding reason to consider closed cycle cooling as the "best available technology economically achievable" with respect to the rejection of waste heat from steam-electric power plants. With closed cycle cooling, a power plant's requirement for water is reduced typically to 2 or 3 percent of the requirement associated with open cycle cooling, leading in principle to a reduction in the number of aquatic organisms destroyed or injured by the operation of the power plant. Orange and Rockland is contesting the requirement for closed cycle cooling at the Bowline Point Station in an adjudicatory hearing before the Environmental Protection Agency (Appendix B). Other utility companies operating power plants sited on the Hudson River and subject to similar requirements to backfit closed cycle cooling systems are parties in the same proceeding, currently in progress.

not true

Airborne Discharges

1.62 Permits to construct the main station boilers have been issued by the New York State Department of Environmental Conservation but certificates to operate the main boilers have been withheld pending the resolution of a question of potential violations of certain New York State regulations related to ambient air quality.

Time element is inconsistent with present time

1.63 A preliminary analysis carried out prior to construction of the station indicated that both hourly and 24-hour average limitations on ambient sulfur dioxide concentrations would be exceeded on the ridge line and peak areas to the southwest of the plant under conditions of strong northeasterly winds (Orange and Rockland, 1971). No problems with respect to particulates or nitrogen oxides were anticipated at the time.

1.64 More extensive analyses (Orange and Rockland, 1972, 1973a) confirmed the findings of the earlier study and pointed to the need for 650-foot stack(s) to circumvent potential problems in meeting ambient air quality standards relating to sulfur dioxide. Orange and Rockland opted to retain the 287.5-foot stacks and implemented an observation program to monitor pertinent meteorological and air quality factors in the vicinity of the site. Plans were drawn up to burn (low sulfur) natural gas during periods when ambient concentrations of sulfur dioxide would be expected to exceed regulatory standards. The company has been unable to secure an adequate supply of gas to implement this strategy.

true ?

1.65 Orange and Rockland is currently under an order on consent from the New York State Department of Environmental Conservation to erect a 650-foot stack or to continue field measurements, carry out plume trajectory studies and report the findings of investigations to the Department of Environmental Conservation on a yearly basis until the matter is resolved. The critical area with respect to potential violations has been identified as the Hightor ridge to the southwest of the plant. A monitoring network (three monitoring stations) has been established where the concentrations of sulfur dioxide are expected to be highest during periods of adverse wind conditions.

1.66 Orange and Rockland has submitted two annual reports to the Department of Environmental Conservation covering the period June 1974 through May 1976. No instances of ambient air quality violations have been reported to date and a certificate to operate the main boilers has been issued by the New York State Department of Environmental Conservation. Meteorological and air quality monitoring are to continue as a condition of operation.

OTHER MAJOR PROJECTS ON THE LOWER HUDSON RIVER

1.67 Pertinent characteristics of generating stations on the lower Hudson River are summarized in Table 1-4, and the locations of these stations are shown in Figure 1-9. The existing seven stations represent a total generating capability of the order of 6,000 megawatts of which approximately 2,000 megawatts is nuclear-fueled capability, 2,400 megawatts is oil-fueled capability, and 1,400 megawatts is coal-fueled capability that has been converted to burn oil. In accordance with the provisions of Section 2 of the Energy Supply and Environmental Coordination Act of 1974 (P.L. 93-319 as amended by P.L. 94-163), the U.S. Federal Energy Administration has issued an order prohibiting the burning of petroleum products at the plants with the capability of burning coal.

1.68 All the existing stations currently operate with open-cycle or once-through condenser cooling systems. The U.S. Environmental Protection Agency has imposed the requirement that closed-cycle cooling systems be installed at the Bowline Point and Roseton Generating Stations and at Units 2 and 3 of the Indian Point station. Conditions to the National Pollutant Discharge Elimination System permits authorizing the discharge of liquid effluents from these stations stipulate that closed-cycle cooling systems be installed and fully operational at various dates in 1981 and 1982. This requirement, in each instance, is being contested and adjudicatory hearings on these matters are presently being held before the U.S. Environmental Protection Agency. No requirements to install closed cycle cooling system at the other stations on the Hudson River Estuary are presently being imposed by the U.S. Environmental Protection Agency.

TABLE 1-4

PERTINENT CHARACTERISTICS OF EXISTING GENERATING STATIONS ON THE LOWER HUDSON RIVER

STATION (COMPANY)	LOCATION (RIVER MILE)		CAPACITY IN MEGAWATTS[1]		YEAR OF INITIAL OPERATION	PRIMARY FUEL	CONDENSER COOLING
			CURRENT	ULTIMATE			
Albany (Niagara Mohawk)	Bethlemen, 142		400	400	1952	Oil/Coal	Open Cycle
Danskammer (Central Hudson)	Newburgh, 66.3		500	500	1951	Oil/Coal	Open Cycle
Roseton[2] (Central Hudson, Con Edison, Niagara Mohawk)	Newburgh, 65.8		1200	1200	1974	Oil	Closed Cycle Required by 7/1/81
Indian Point[3] (Con Edison, Power Authority	Buchanan, 43	Unit 1	0	262	1962	(4)	Open Cycle
		Unit 2	864	1042	1973	Nuclear	Closed Cycle Required by 5/1/82
		Unit 3	965	1033	1976	Nuclear	Closed Cycle Required by 9/15/82
Lovett (Orange and Rockland)	Tompkins Cove, 41.5		500	(+400)	1949	Oil/Coal	Open Cycle
Bowline Point[5] (Oraange and Rockland, Con Edison)	Haverstraw, 37.5		1200	(+400 to 600)	1972	Oil	Closed Cycle Required by 7/1/81
59th Street (Con Edison)	Manhattan, 5		82	82	1918	Oil	Open Cycle

[1] Exclude gas turbine capability

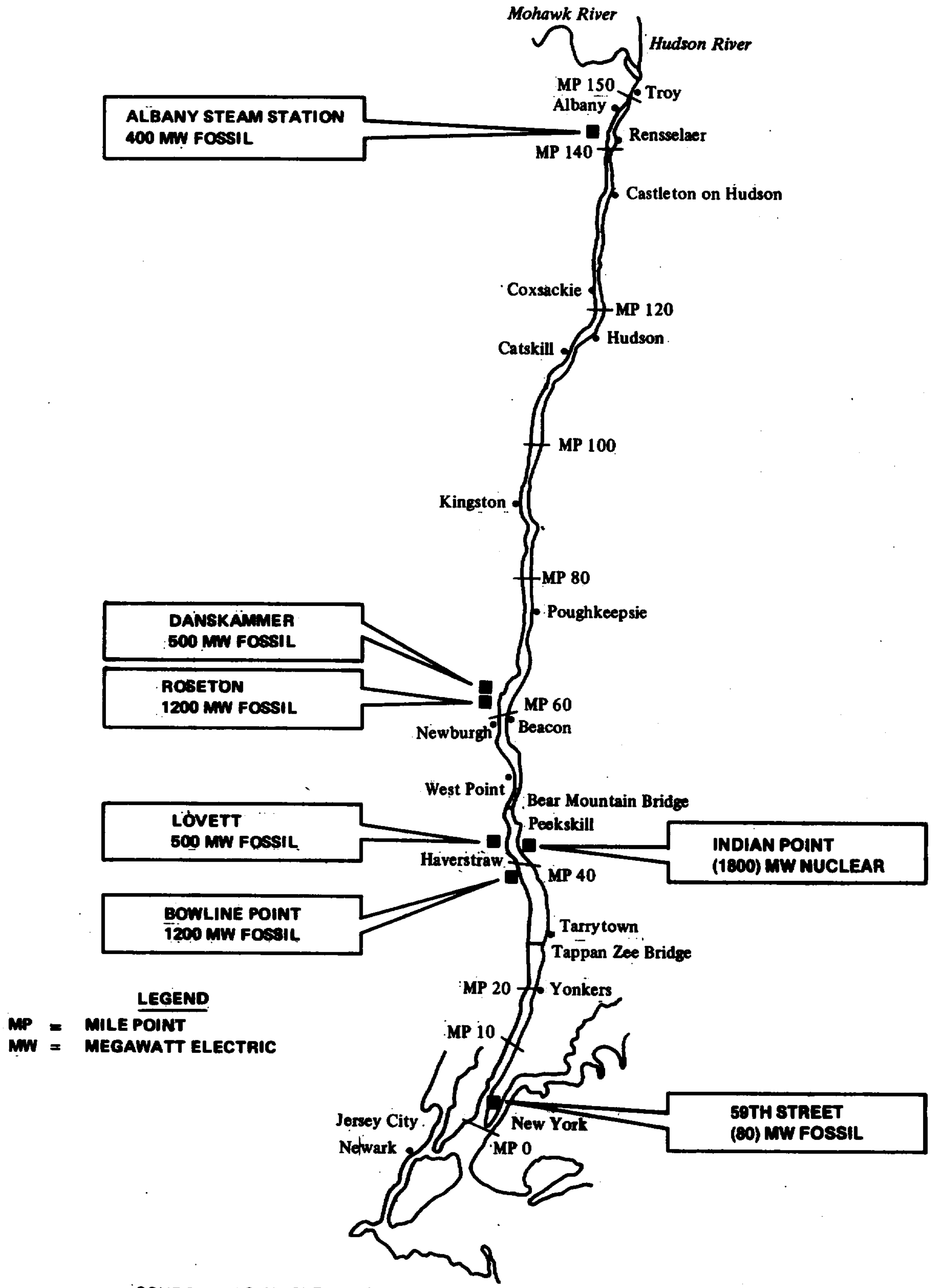
[2] Central Hudson's share of capability is 360 megawatts; Con Edison's share is 480 megawatts; Niagara Mohawks's share is 360 megawatts.

[3] Ownership of Unit 3 was transferred from Con Edison to the Power Authority of the State of New York on 31 December 1975.

[4] Indiana Point Unit No. 1 is a nuclear unit with oil-fired superheat; it is considered by Con Edison to be inoperable pending the installation of an emergency core cooling system.

[5] Orange and Rockland's share of capability is 401 megawatts; Con Edison's share is 801 megawatts.

Source: New York Power Pool, 1979.



SOURCES: U.S. NUCLEAR REGULATORY COMMISSION, 1975; NEW YORK POWER POOL, 1976.

FIGURE 1-9
EXISTING POWER GENERATING STATIONS
ON THE HUDSON RIVER ESTUARY

Albany Steam Station

1.69 The Albany site, owned by Niagara Mohawk, currently accommodates four oil-fueled units, each of 100-megawatt capacity, which has been and in operation since 1952. The approximate ultimate capacity that the site can support is estimated to be 800 megawatts (New York Power Pool, 1976).

1.70 No additions to the site are currently proposed or contemplated (New York Power Pool, 1976). A major constraint on future expansion of the plant is considered to be the limitation of the river as a source of cooling water. The visibility of natural draft cooling towers and their potential to induce fogging are additional factors that would inhibit expansion of the Albany site (New York Power Pool, 1976).

update to 1980

Danskammer

1.71 The Danskammer Point Generating Station comprises four oil-fired units with an aggregate generating capacity of 472 megawatts. The oldest units have been in operation since 1951. There are no plans at present to uprate the station or to install additional generating capacity at the Danskammer site.

date this?

Roseton

1.72 The Roseton site occupies 133 acres in the Village of Roseton, Town of Newburgh, Orange County, New York. The station comprises two fossil-fueled units with a combined net capability of 1,200 megawatts. There are no plans at present to install additional generating capacity at the Roseton site.

Indian Point

1.73 The Indian Point Nuclear Generating Station is located in the Village of Buchanan, Westchester County on a 239-acre site on the east bank of the Hudson River at Mile Point 43. The generating facilities occupy 35 acres of the site (U.S.Nuclear Regulatory Commission, 1975) and include Indian Point Units 1, 2, and 3. Units 1 and 2 are owned by Con Edison. Ownership of Unit 3 was transferred from Con Edison to the Power Authority of the State of New York on 31 December 1975.

1.74 Unit 1, supplied by the Babcock and Wilcox Company, is of unique design in that it features a pressurized water reactor with oil-fired superheating of the main steam. A construction permit for the unit was issued by the Atomic Energy Commission in 1956 and the unit was first put into service on 30 September 1962, under an operating license issued earlier in that year. The unit has been shut down since 31 October 1974 for the purpose of installing an emergency core cooling system (U.S. Nuclear Regulatory Commission, 1975). The date on which the unit will resume service is undetermined. Accordingly, the New York Power Pool generation plan (1976-1991) excludes any contribution from Unit 1 (New York Power Pool, 1976).

has been decommissioned

1.75 Units 2 and 3 incorporate pressurized water reactors supplied by the Westinghouse Corporation. Construction permits for Units 2 and 3 were issued by the Atomic Energy Commission, in 1966 and 1969 respectively. A license to operate Unit 2 at 100 percent steady-state power was issued on 28 September 1973. The Nuclear Regulatory Commission issued the final environmental statement related to the operation of Unit 3 (operating license) in February 1975 (U.S. Nuclear Regulatory Commission, 1975) when commercial operation was anticipated in the latter half of 1975. Commercial operation of Unit 3 began in August 1976.

date

date

1.76 The generating capacities of the Indian Point units, excluding possible deratings as a result of installing closed-cycle cooling systems, are as follows:

UNIT	CURRENT (1979) CAPACITY (megawatts)	POTENTIAL UPRATINGS (megawatts)	ULTIMATE CAPACITY (megawatts)
1	0	--	265
2	864 true?	169 being considered now	1033
3	965	68	1033

Source: U.S. Nuclear Regulatory Commissions, 1975; New York Power Pool, 1979.

Lovett Station

1.77 The existing Lovett Station is owned by Orange and Rockland and located in Tomkins Cove, Rockland County at Mile Point 41.5 on the west bank of the Hudson River. The station comprises five oil fueled units, with an aggregate generating capability of 506 megawatts. Commercial operations at the Lovett Station began in 1949.

date

1.78 There are currently no plans (through 1991) to uprate or retire any of the ~~generating~~ units. Initial studies indicate that a further 400 megawatt oil-fueled unit could be supported by the existing site with some additional acquisition of property (New York Power Pool, 1976). The addition would entail the need to upgrade or expand the existing transmission facilities and some landfill work in the Hudson River in the northern portion of the site.

retire ?

Bowline Point Generating Station

1.79 No detailed evaluation of the total generating capability that could be installed at the present Bowline Point site has been made to date. Initial studies indicate that the site could support an additional 400 to 600 megawatts of capacity (New York Power Pool, 1976). The most logical addition would appear to be a single coal/oil fueled unit that would raise the present station capacity of 1,200 megawatts to an ultimate capacity of 1,600 to 1,800 megawatts. The addition would entail relatively minor upgrading or expansion of transmission, transportation, and fuel handling facilities. There are, at present, no plans to increase the generating capability of the Bowline ~~Point~~ Generating Station.

site

59th Street Power Plant

1.80 The 59th Street plant is a common header station owned in fee by Con Edison and located in Manhattan at Mile Point 5 on the east bank of the Hudson River. In addition to the conventional thermal units, the plant houses two kerosene-fired gas turbine units with a combined sustained capacity of 28 megawatts in summer and 36 megawatts in winter, and a combined maximum capacity of 34 megawatts in summer and 40 megawatts in winter.

Future Power Plant Developments

1.81 Substantive changes in the long term generation plans of the New York Power Pool have been made in the past few years. Included in these changes are the deferral or cancellation of a number of power plant projects on the Hudson River estuary at one time proposed or considered as likely developments. According to the New York Power Pool's most recent plan covering the period 1979 through 1994, there are no major expansions of existing facilities on the Hudson River or new construction scheduled within this period (New York Power Pool, 1979).

cite 1990 report

1.82 Upratings of power plants on the Hudson River estuary are limited to ~~an increase of 9 megawatts~~ in the capability of Indian Point Unit ~~2 to be effected in 1979~~ (New York Power Pool, 1979). Provisions in the original design of both units at Indian Point would

Never realized -

allow the capability of each unit to be raised ultimately to levels discussed previously. These upratings would entail no major site preparation or installation of new equipment.

Possible Future Project

1.83 All of the future projects on the Hudson River estuary at one time included in the New York Power Pool's generation plans are now considered as indefinite possibilities that could materialize in the 1990's or beyond. These projects consist of the Cornwall pumped storage hydroelectric project, the Greene County Nuclear Power Plant, the NYSE&G Nuclear project and the Mid-Hudson West project.

1.84 Cornwall. Originally announced by Con Edison in 1962, the Cornwell pumped storage hydroelectric project comprises an upper reservoir around Whitehorse Mountain to the south-southwest of Storm King Mountain and pumping/generating facilities on the Hudson River at Cornwall Landing. The Federal Power Commission approved the project in 1965 but, following an appeal by several conservation groups allied as the Scenic Hudson Preservation Conference, was ordered by the U.S. Court of Appeals to review its approval of the project, giving due consideration to the effects the project might have on the environment.

1.85 Public hearings on the projects have been held at various times. If the Federal Power Commission ultimately authorizes the project, an estimated maximum capacity of 3000 megawatts could be installed at the site (New York Power Pool, 1976).

1.86 Green County. Plans to construct the Green County Nuclear Power Plant (U.S. Nuclear Regulatory Commission, 1976) near the Hamlet of Cemeton have been cancelled by the Power Authority of the State of New York (Nucleonics Week, 12 April 1979). As an alternative to the proposed 1200-megawatts nuclear power plant, the Power Authority intends to seek the necessary approvals to construct coal-fired facilities in Green County or elsewhere in the state. It is unknown at present whether the alternate capacity would be brought on line by late 1989, the date scheduled for the operation of the Green County Nuclear Power Plant according to the New York Power Pool's "energy strategy" plan (New York Power Pool, 1979).

canceled?

1.87 NYSE&G Nuclear. As currently projected, the NYSE&G Nuclear power plant proposed jointly by Long Island Lighting Company and New York State Electric and Gas Corporation would be located at New Haven, New York on Lake Ontario (New York Power Pool, 1979). Now designated the New Haven project, the power plant would comprise two nuclear units, each of 1,250 megawatts capacity, scheduled to be operational in 1992 and 1994.

deferred?

1.88 A site at Stuyvesant in Columbia County on the east bank of the Hudson River Estuary is being considered as an alternative to the New Haven site. Coal as an alternative to nuclear fuel is receiving consideration for both the New Haven and Stuyvesant sites.

1.89 Mid-Hudson West. An announcement related to a large generating complex, comprising five base load units scheduled to come into service between 1984 and 1991, was first made by Con Edison in 1973 (Nuclear Industry, 1973). Details concerning the type of units and site were not disclosed. The most likely location was described at the time as a site on the west bank of the Hudson River, north of Newburgh and behind the first row of hills along the shore. Con Edison was simultaneously evaluating alternative sites on both banks of the Hudson River north of the Poughkeepsie as well as sites on Lake Ontario and the St. Lawrence River.

1.90 Plans relating to the Mid-Hudson West project are presently indefinite. Consideration is being given to nuclear or coal fueled facilities, possibly to be located at the Red/Hook/Clermont site along the Columbia Dutchess county line on the east bank of the Hudson River Estuary.

no longer current

Siting Options

1.91 A number of sites on the Hudson River have been tentatively characterized as capable of meeting the technical requirements of large generating facilities and as acceptable in terms of current environmental standards. A survey* of candidate sites for the Greene County Nuclear Power Plant (U.S. Nuclear Regulatory Commission, 1976) identified nine potential alternatives,** most deemed suited as sites for fossil-fueled plants as well, on both banks of the Hudson River between Newburgh to the south and Hudson to the north.

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[*] The specific criteria used by the Power Authority of the State of New York in the evaluation of siting alternatives are the following: impact on air quality, impact on water quality; environmental compatibility of once-through cooling (including hydrothermal criteria and impact on aquatic ecology), environmental compatibility of closed cycle cooling (including space availability, fogging and icing effects, drift effects and height limitations of natural draft towers), visual and social impacts, present and future land use, population density, impacts on terrestrial ecology, meteorology and engineering feasibility.

[**] Closed-cycle cooling was found to be a prerequisite in all nine cases.

1.92 Initial findings indicated that among the sites, four would be less favorable than the others for various reasons, including distance to the source of water, potential foundation problems and the possibility of flooding. Further assessment of the five remaining sites--the Denning Point site within the City of Beacon, Dutchess County; the Lloyd site in the Town of Lloyd, Ulster County; the Cruger Island site in the Town of Red Hood, Dutchess County; the Cementon site in the Town of Catskill, Greene County; and the Athens-Leeds site in the Town of Athens, Greene County--established the relative advantages and disadvantages of each site and demonstrated that the Cementon and Athens-Leeds would be preferable. A final selection of the Cementon site was made on the basis of certain financial and socioeconomic factors.

1.93 The review of this selection by the U.S. Nuclear Regulatory Commission in 1976 reveals only small differences in the indices of merit assigned to each site, particularly the sites chosen in the latter stages of the screening process. With information now available, there are no indications that these sites would be rejected as potential candidates for future projects.

1.94 In addition to the above sites, the member companies of the New York Power Pool have some form of possessory interest in a number of other undeveloped (with respect to power generation facilities) sites. Several among these are on the Hudson River. Although there are no current plans to develop these sites on or before 1991 (New York Power Pool, 1976), their potential for development is considered briefly in the following sections.

true?

1.95 Verplanck. The Verplanck site occupies 142 acres in the Village of Buchanan and is owned by Con Edison. The site is in close proximity to the Indian Point generating facilities. Con Edison contemplates the installation of 800 megawatts of gas turbine capacity at some time in the future beyond 1991, if the company is unable to site the gas turbines closer to load centers and transmission facilities (New York Power Pool, 1976).

1.96 Since the Verplanck site is part of an industrial tract that presently includes the Indian Point Station, land use restrictions are not considered to be an impediment to the future development of the site. In accordance with Title 6, New York State Official Compilation of Codes, Rules and Regulations, Part 660, a Tidal Wetlands Moratorium Permit would have to be secured if the development of the site would entail a significant effect on the existing condition of any tidal wetland area.

1.97 Ward Manor. The Ward Manor site occupies 768 acres in the Town of Red Hook, Dutchess County, the site is owned by Central Hudson and includes Cruger Island, one time an island in the Hudson River but now a peninsula linked to the mainland by alluvial deposits (U.S. Nuclear Regulatory Commission, 1976).

1.98 Although no determination has been made to date of the maximum generating capacity that could be supported by the site and Central Hudson has no plans to develop the site, the general area has been identified as a potential candidate site for the Green County Nuclear Plant. By a zoning ordinance adopted in July 1974, the Town of Red Hook has designated the area for residential development on minimum 5-acre plots. Construction of generating facilities at this site, therefore, would require rezoning of the portions of the site required for the facilities (New York Power Pool, 1976).

1.99 Terry Brickyard. The 94-acre Terry Brickyard site in the Town of Ulster is owned by Central Hudson. No determination has been made to date of the maximum generating capacity that could be supported by the site. The site was formerly occupied by a brickyard. The Town of Ulster has no zoning ordinances. However, the Ulster County master plan indicates that the portion of the Town of Ulster in which the site is located is designated for future industrial development. The general area of the site has not been identified as a potential candidate for the Greene County Nuclear Power Plant.

1.100 Greene Point. The Greene Point site occupies 348 acres in the Town of Catskill. The site is owned by Central Hudson and is in proximity to the Cementon site selected for the Greene County Nuclear Power Plant. There are no zoning ordinances or master plans that indicate any preferred type of development for the area in which the site is located.

1.101 Easton. The Easton site is owned by Niagara Mohawk and is located in Washington County, on the east bank of the Hudson River directly across from the Saratoga National Historical Park. The site was originally purchased for a nuclear power plant, but the project did not materialize. The ultimate generating capacity that the site can support is estimated to be 600 megawatts. The site is well to the north of the Albany-Troy area.

Other Future Developments

1.102 On 27 October 1965, the 89th Congress authorized the Northeastern United States Water Supply (NEWS) Study and authorized the Secretary of the Army, acting through the Chief of Engineers, to prepare plans to meet the long-range water supply need of the Northeast in cooperation with Federal, State and local agencies.

1.103 The Hudson River Project is designed to operate intermittently and to utilize directly the flows of the Hudson River to supplement an existing regional water supply system during periods of deficit and to expand the conveyance system in New York City and Nassau County. The project would involve the construction of a water intake structure, pumping station, water treatment facility and a tunnel through deep rock. Water would be withdrawn from the Hudson River at a maximum rate of 950 million gallons per day, increasing the safe yield of the supply system by 400 million gallons per day. The project intake would be above (River) Mile Point 86 and below Mile Point 95, between Esopus and Rhinebeck, New York. Two tunnel routes on the west bank and one route on the east bank, all leading to Kensico Reservoir in Westchester County, have been considered. Construction would take 8 years and 11 million cubic yards of rock would be excavated. The material excavated could be used for aggregate or for reclamation of abandoned quarries and gravel pits. The project would also entail completion of portions of New York City Water Tunnel No. 3 and rehabilitation of an existing pipeline between the New York City system and Nassau County. A draft environmental statement has been prepared by the North Atlantic Division, U.S. Army Corps of Engineers and filed with the Council on Environmental Quality (U.S. Army, 1977).

CHAPTER 2

ENVIRONMENTAL SETTING OF THE PROJECT

2.01 The environmental setting of the Bowline Point Generating Station is defined broadly as the lower valley of the Hudson River, a 150-mile corridor extending from the Battery on Manhattan to the Federal Dam at Troy, New York. An extensive study area has been selected expressly to assess both the localized impacts due to the Bowline Point station and the cumulative impacts of other existing major power plants on the Hudson River. As will become evident, there are reasons to suggest that the study area constitutes a distinct natural and ecological system. Further, the region is one in which impacts and resources--physical, biological and human--can be related meaningfully.

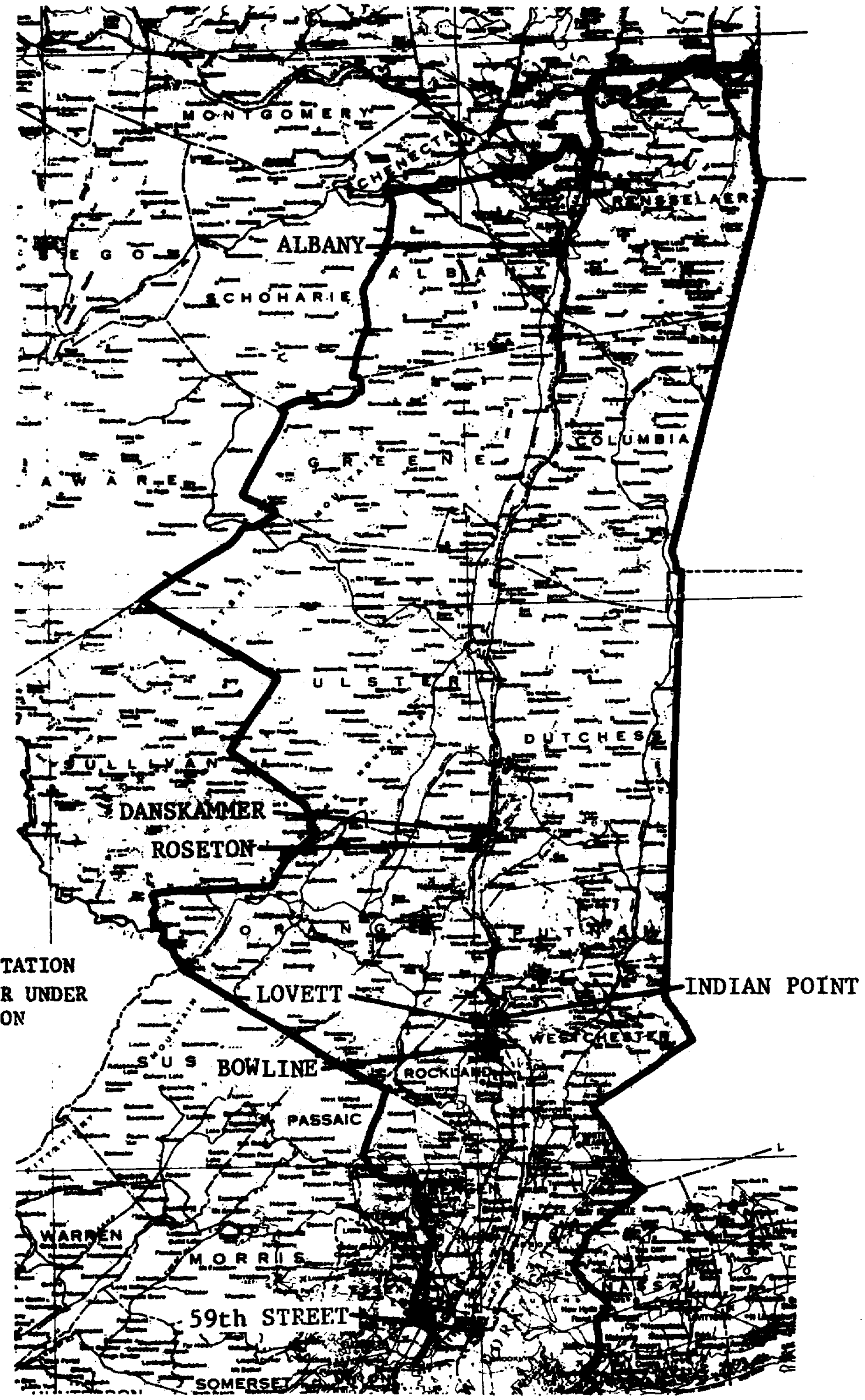
2.02 The study area is composed of the counties in New York and New Jersey that lie on both banks of the Hudson River over its tidal portion (Figure 2-1). In New York, these counties are Albany, Rensselaer, Greene, Columbia, Ulster, Dutchess, Orange, Putnam, Rockland and Westchester and, in New Jersey, Bergen and Hudson Counties. Wherever appropriate, the City of New York is treated as a single entity within the study area.

GENERAL

2.03 The Hudson River begins as a small stream flowing out of the Lake Tear in the Clouds on Mount March in Essex County, New York. Its entire length of 306 miles lies in the State of New York. From its source 4,322 feet above sea level in the Adirondack Mountains, the river winds for more than 100 miles in a south-southeasterly direction to Corinth, then east to Glens Falls and neighboring Hudson Falls. From there it flows for 45 miles almost directly south to the head of the tide at the Federal Dam at Troy, about 150 miles upstream of its mouth. Below Troy, the river passes through an industrial and agricultural area and enters the colorful Hudson Highlands region about 60 miles south of Albany. For 16 miles it winds through a narrow valley with high cliffs rising steeply from both shores. The river widens at Indian Point and reaches its greatest width of 3 1/2 miles at Haverstraw Bay. Continuing south, the river is bordered to the west by the sheer cliffs known as the Palisades and widens into upper New York Bay at the Battery on the southern tip of Manhattan Island.

2.04 The Hudson River is one of the major commercial and recreational waterways in the northeastern United States. The U.S. Army, Corps of Engineers, maintains a channel in the river as far north as Waterford. There the Hudson River is joined by the New York

SITE AREA



■ EXISTING STATION
▲ PROPOSED OR UNDER CONSTRUCTION

FIGURE 2-1

STUDY AREA AND LOCATION OF EXISTING STEAM-ELECTRIC POWER PLANTS

State Barge Canal, a 500-mile system of canals and riverways that links the lower Hudson to the Great Lakes and, through Lake Champlain, to the St. Lawrence River. Connections are provided to Utica, Syracuse, Rochester, Cayuga Lake and Seneca Lake. The Hudson River is navigable by small oceangoing vessels as far as Albany, and the New York State Barge Canal is navigable by shallow draft vessels. The waterways are heavily traveled by commercial vessels, carrying principally petroleum and petroleum products, sand, gravel, crushed rock and coal. Pleasure boat traffic is considerable during the warmer months, but passenger service on the river is limited to excursion trips operating from the New York City area. The lower river is open year-round to Albany and the navigation season is 12 months for oceangoing vessels and 8 months for barges.

2.05 Settlement of the Hudson River valley by the Dutch began in the mid-1620's, following the discovery of the river by the Florentine navigator Giovanni da Verrazano in 1524 and the later exploration in 1609 of Henry Hudson, an English sea captain employed by the Dutch West India Comapny. Fortified trading posts were established in the area of present day Albany and New York City. The small colony of New Amsterdam on the southern tip of Manhattan grew within the first few years of settlement and its safe harbor saw increasing numbers of commercial vessels plying the coastal trade between New Amsterdam and English settlements in New England and Virginia. The harbor and river, by early accounts, teemed with salmon, striped bass, sturgeon and shellfish.

2.06 Growth of the hinterlands was slow throughout the colonial period but increased rapidly in the 19th century. Robert Fulton established steam navigation in North America with the maiden voyage of the Clermont on the Hudson River in 1807. Completion of the 363-mile Erie Canal between Albany and Buffalo in 1825 had a profound influence on the development of the state, providing, among other things, cheap transportation for the agricultural and manufactured products from western New York and beyond to the Atlantic seaboard. The transportation system of the state was further expanded and reinforced in the 1850's by the consolidation of several small rail lines into the New York Central Railroad running between Albany and Buffalo. Albany was next linked to New York City by the New York and Harlem Railroad and the Hudson River Railroad. Today's principal transportation corridors and lines of communication were forged.

2.07 Industry prospered over the same period along the lower Hudson River. The river towns of Hudson, Poughkeepsie and Newburgh owed their early prosperity to the whaling fleets and processing of whale products. Other industries soon developed and other settlements along the river grew in importance as centers of industry and commerce, among them Tarrytown, Nyack, Ossining, Haverstraw, Peekskill, Beacon, Kingston, Saugerties, Catskill, Troy, Cohoes and Glens Falls. Industries that became established included quarrying and brickmaking, lumbering, fishing, leathermaking and the storage of ice cut from the river in winter. Some of the industries vanished and other developed during the 20th century. Mushrooms were cultivated where ice once was stored, and sawmills began disappearing as lumbering in virgin forests receded further into the mountains. Quarrying of bluestone and cement manufacturing became important industries. The availability of water and increasing demand for electrical energy as the lower Hudson River valley grew into one of the nation's major centers of manufacturing lead to the siting of steam electric plants on the river since the earliest years of the electric utility industry. Transmission lines become established roughly along the major transportation routes as individual utilities merged gradually to form the integrated supply network that exists today.

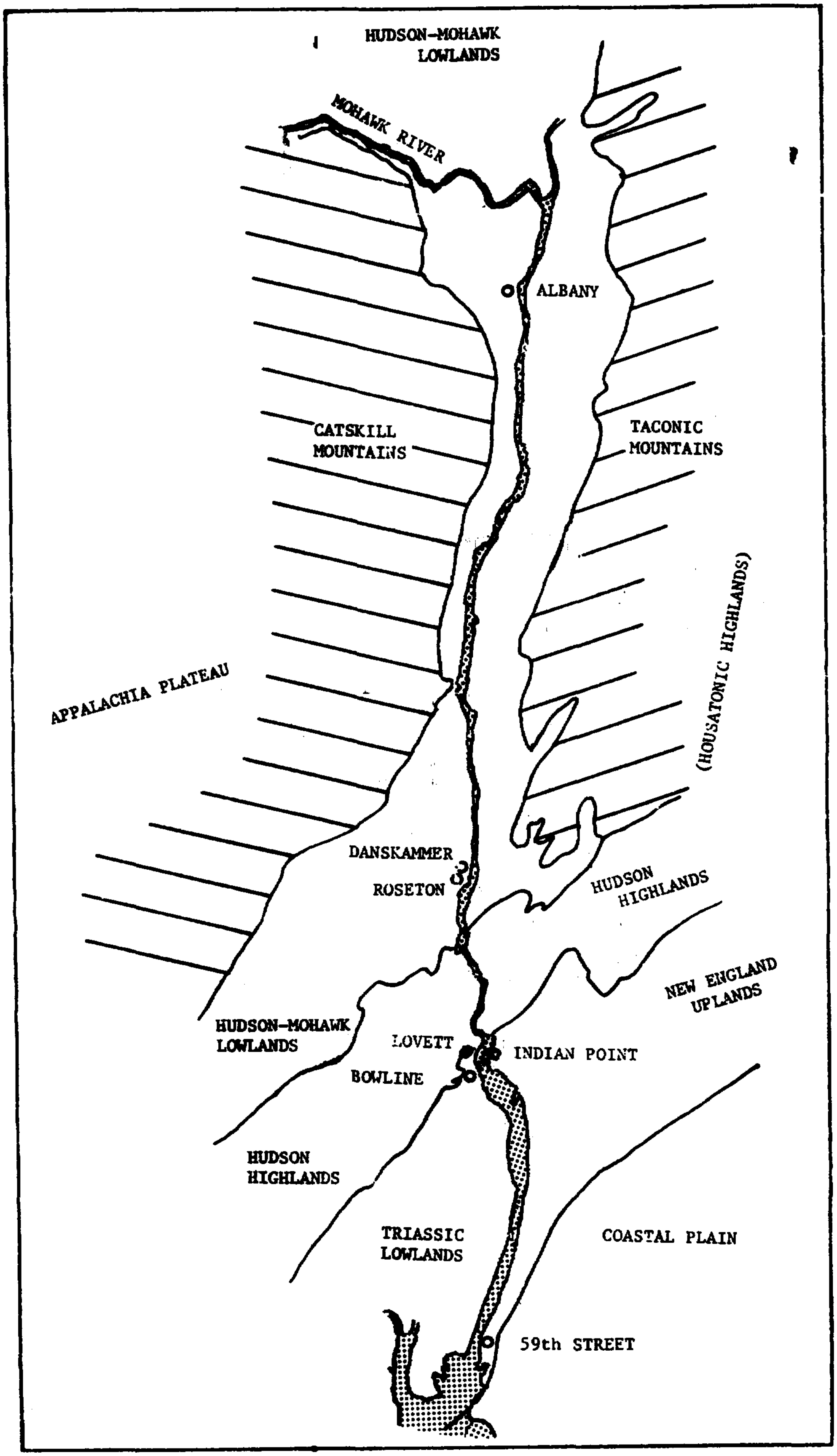
PHYSICAL SETTING

2.08 The Hudson River estuary extends over an area of approximately 6,700 square miles. Below Albany, the land becomes open country except where the Catskills and the Hudson Highlands cut through the Hudson Valley. South of the Highlands, the basin again becomes open country with the high cliffs of the Palisades forming the west bank of the Hudson River.

Physiography

2.09 The entire Hudson River Basin lies in six physiographic provinces--St. Lawrence-Champlain Lowlands, Adirondack Highlands, Hudson-Mohawk Lowlands, Appalachian Uplands, New England Uplands and Triassic Lowlands (Roughton et al., 1962). The St. Lawrence-Champlain Lowlands Province includes the St. Lawrence River Valley northeast of the Thousand Islands, the Low rolling hills that border this valley to the south, and the Lake Champlain Valley. The Adirondack Highlands Province includes the highest mountains in New York State, especially in the High Peak areas of the east-central Adirondack Mountains. Both these provinces lie beyond the study area; the Hudson River estuary lies within portions of the remaining four provinces, as shown in Figure 2-2.

2.10 The Hudson-Mohawk Lowlands province is a northward extension of the Valley and Ridge Province of eastern North America. Topography of the lowlands has been developed by erosion of weak rock outcrop belts that, in the case of the Mohawk Lowlands, lie between the Adirondacks and a series of steep limestone escarpments known as the Helderbergs. The Hudson Lowlands lie between the Catskills to the west and the metamorphosed shale hills of the Taconic Mountains



Source: Broughton et al., 1962.

FIGURE 2-2

PHYSIOGRAPHIC PROVINCES OF THE STUDY AREA to the east. For the most part, the lowlands have low elevations and relief.

2.11 The Catskill Mountains form the eastern fringe of the Appalachian Uplands, a major area of the State of New York and a part of the Appalachian Plateau. Relief is high to moderate throughout the Appalachian Uplands, the highest peak being Slide Mountain (4,202 feet) in the Catskill Mountains.

2.12 The New England Uplands Province is an area of great geological complexity and diversity. The area encompasses the Hudson Highlands and the hilly country (Taconic Mountains) between the Hudson River and the Massachusetts, Connecticut and Vermont state lines. Rocks in this province are either metamorphic or igneous, and the land forms show a close relationship to the relative durability of these rocks. The Hudson Highlands, a northeast trending upland of Precambrain rocks, are an extension of the New Jersey Highlands to the south and continue into the Housatonic Highlands to the north. The Hudson Highlands have the greatest relief within the province, with elevations ranging from 800 feet below sea level (bedrock of the Hurson River Valley) to more than 1,600 feet. Most of the ridges and valleys in the Hudson Highlands follow the northeast-southwest strike of the metamorphosed rocks so that strong topographic linearity characterizes this part of the province. The Taconic Mountains have a general north-south trend dependent on the strike of the schist that forms the hills and the limestone in the valleys. An exception is the Rensselaer Plateau, a rolling plateau surface with relief of more than 500 feet. This area, about 20 miles long (north-south) by 9 miles wide (east-west) is held up by the resistant Rensselaer graywacke.

2.13 The Triassic Lowlands area is unique in New York State. The portion of the province within the state lies entirely in Rockland County and is bounded on the east by Palisades sill and on the north by the sill and the Triassic border fault. Shales and sandstones lie both over and under the diabase sill, but those beneath are mainly covered by Hudson River waters. Drainage in the overlying shales is to the south and is generally controlled by north-south joints. The oustandings feature of the province is the Palisades, a north-south escarpment developed on the diabase sill that forms the west bank of the Hudson River from Nyack south to Staten Island. The scarp has been cut in several places by faults along which erosion has developed narrow cross valleys.

2.14 The geomorphology of the Hudson drainage basin has been influenced substantially by the glaciations of the Pleistocene age. The river valley, which paralleled the general north-south direction of ice advances and retreats, was deepened into a typical glacial trough with U-shaped cross-section, leaving tributaries hanging high above the new valley floor. During glacial retreat and subsequent flooding with the rise in sea level, the deep trench, in places up to 750 or 800 feet in depth, was partially filled in by debris and glacial till. The trench, in its present form, is the Hudson River Channel.

2.15 The Bowline Point Generating Station is located in the Triassic Lowlands. Other generating facilities on the Hudson River north of the Hudson Highlands, including the Roseton facility, lie in the Hudson-Mohawk Lowlands.

2.16 The Northeastern Region of the United States, defined as New England and New York by the National Oceanic and Atmospheric Administration for the purpose of of listing and describing earthquakes, contains zones of relatively high seismic activity (U.S. Department of Commerce, 1973a). New York and Massachusetts have experienced several severe shocks. This region is affected also by large earthquakes originating in adjacent Canada, principally in the St. Lawrence Valley and the Laurentain Trough. Earthquakes in the region may be explained by the readjustment of the crust following the recent Ice Age. Some geologists suggest that the earth's crust, deformed by the ice load during glacial periods, is gradually returning to its normal position. Adjustments may occur at great depths without producing major surface faulting (U.S. Department of Commerce, 1973a).

2.17 The general area of major seismic risk in New York lies to the north of a line extending from the southwestern corner of the state on Lake Erie to the New York-Vermont state line on the Canadian border. All of southeastern New York up to a point south of the Albany-Troy area and part of the Southern Tier of the state is in an area of minor risk. The remainder of the state is an area of moderate seismic risk (U.S. Department of Commerce, 1976a). Thus, the study area lies within a zone considered to be of minor seismic risk, with the exception of Albany and Rensselaer Counties, which mark the transition into a zone of moderate seismic risk.

Climate

2.18 The climate* of the Hudson River Estuary is characterized as humid continental, the type that prevails throughout the northeastern U.S. Dominant continental characteristics stem from the frequent invasions of cold, dry air masses from the northern interior of the continent alternating with warm, humid air transported by

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*Material on climate in the study area is derived mainly from Pack, 1972.

south and southwesterly winds from the Gulf of Mexico and adjacent tropical waters. A third flow of air affects the climate of New York, particularly in the southeastern portion. A great air mass flows inland from the North Atlantic Ocean and produces cool, cloudy and damp weather. Although important, the maritime influence is secondary to the more prevalent air flows across the continent.

2.19 Average annual mean temperatures throughout the state vary between 40 F in the Adirondack Mountains to near 55 F in the New York City area. Average January temperatures range from 16 F the Adirondacks to 26 F in the lower Hudson River Valley. The moderating influcence of the Atlantic Ocean is such that New York City experiences subzero minimum temperatures in two or three winters out of 10, with low temperatures generally near -5 F. The lower portions of the Hudson River Valley have rather warm summers with periods of high, uncomfortable humidity. Summer daytime temperatures range from the upper 70s to the mid-80s. Temperatures of 90 F or higher occur from late May to mid-September throughout the Hudson River Estuary. The New York City area and most of the Hudson River Valley record an average of 18 to 25 days with such temperatures during the warm season. While temperatures in excess of 100 F are rare, many weather stations in the southern portion of the state have recorded temperatures of 100 F to 105 F on occasions. In the Adirondack Mountains the summer climate is considerably cooler, adding to the area's attractiveness as a year-round resort.

2.20 The average annual precipitation in the Hudson River basin is 42 inches, generally evenly distributed throughout the year. No distinctly dry or wet seasons occur regularly from year to year. However, long-term records indicate that the greatest precipitation occurs in the spring and fall. Since the drought of 1964, summer rainfalls in excess of the average 4 inches per month have been recorded in the Hudson River Valley. Annual precipitation may be as high as 50 inches in the Catskills. The Catskill highlands in Ulster (and Delaware and Sullivan Counties) record heavy snow accumulations averaging 100 to 120 inches per year. The moderating influence of the Atlantic Ocean reduces the snow accumulation to 25 to 35 inches in the New York City area. Minimum seasonal snowfalls of 40 to 50 inches occur near the Hudson River in Orange, Rockland, and Westchester Counties and upstream to the southern portion of Albany and Rensselaer Counties.

2.21 Although major floods are relatively infrequent, the greatest potential for flooding occurs throughout the State in the early spring when subatantial rains may combine with rapid snow melt to produce heavy runoff. Several of these floods have occurred since the turn of the century in the river basins of southern and eastern New York. At other times of the year damaging floods occur after prolonged periods of rainfall. Examples in recent years are the floods in the lower Hudson River Valley in May 1968 and in the Catskill Mountains in July 1969. In addition, the New York City area and other heavily urbanized areas are subject to severe flooding of highways, streets, and low-lying ground.

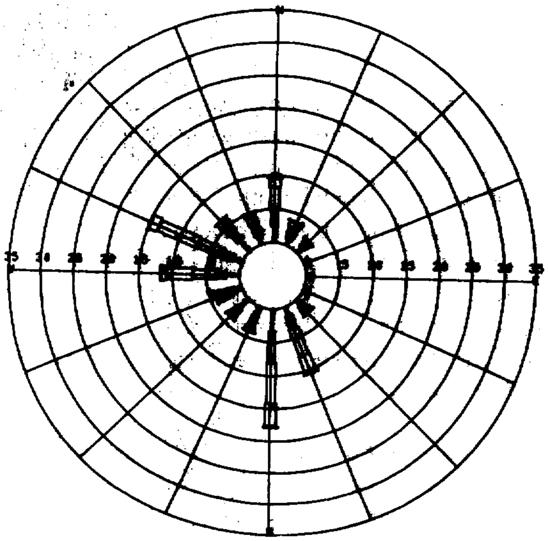
2.22 The prevailing wind is generally from the west throughout all of New York State. A southwest component become evident during the warmer months while a northwest component is characteristic of the colder half of the year. Wind patterns within the Hudson River estuary, however, are substantially influenced by terrain, particularly where relatively pronounced differences in elevation occur between the valley and adjacent ridges. This influence is such that winds on and above the river are often upstream by day and downstream by night. Annual wind roses pertaining to three selected locations within the study area are shown in Figure 2-3.

2.23 Annual wind roses derived from meteorological observations at the Bowline Point and Roseton generating stations (Orange and Rockland, July 1976; Central Hudson, 1976) are shown in Figure 2-4. The differences in wind patterns prevailing at the two sites reflects the strong influence of topography. Local winds at Bowline Point are predominantly from the northwest quadrant over the year, with a secondary maximum in the distribution due to the southerly winds of the summer months. Further details of wind direction frequencies by calendar quarter and stability class, as observed at the Bowline Point station between June 1975 and May 1976 (Orange and Rockland, 1976) are summarized in Table 2-1. Dominant wind directions at Roseton are north-northeast and south-southwest, roughly parallel to the river channel at the site. Available information derived from observations at the Roseton Generating Station between December 1974 and February 1975 (Central Hudson Gas and Electric, 1975) is given in Table 2-2.

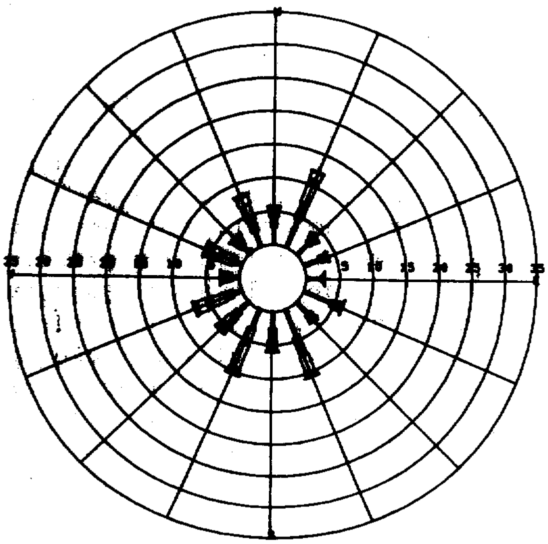
Hydrology

2.24 The Hudson River drains a total area of 13,400 square miles, most of which lies within New York State, with small portions of the basin extending into Vermont, Massachusetts, Connecticut and New Jersey (U.S. Department of the Interior, 1972). Approximately 8,100 square miles or 60 percent of the drainage basin is upstream of the Federal Dam at Troy. The remaining portion drains into the estuarine portion of the river.

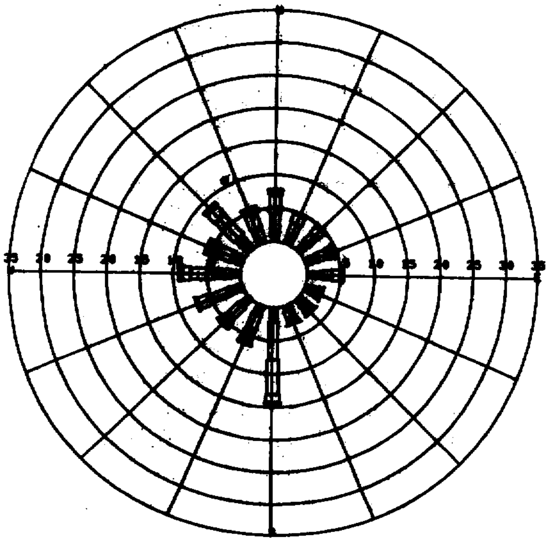
2.25 South of the Hudson-Mohawk confluence, the Hudson River is joined by only three major tributaries, namely, the Wallkill River



ALBANY
(1960-1964)



POUGHKEEPSIE
(1950-1954)

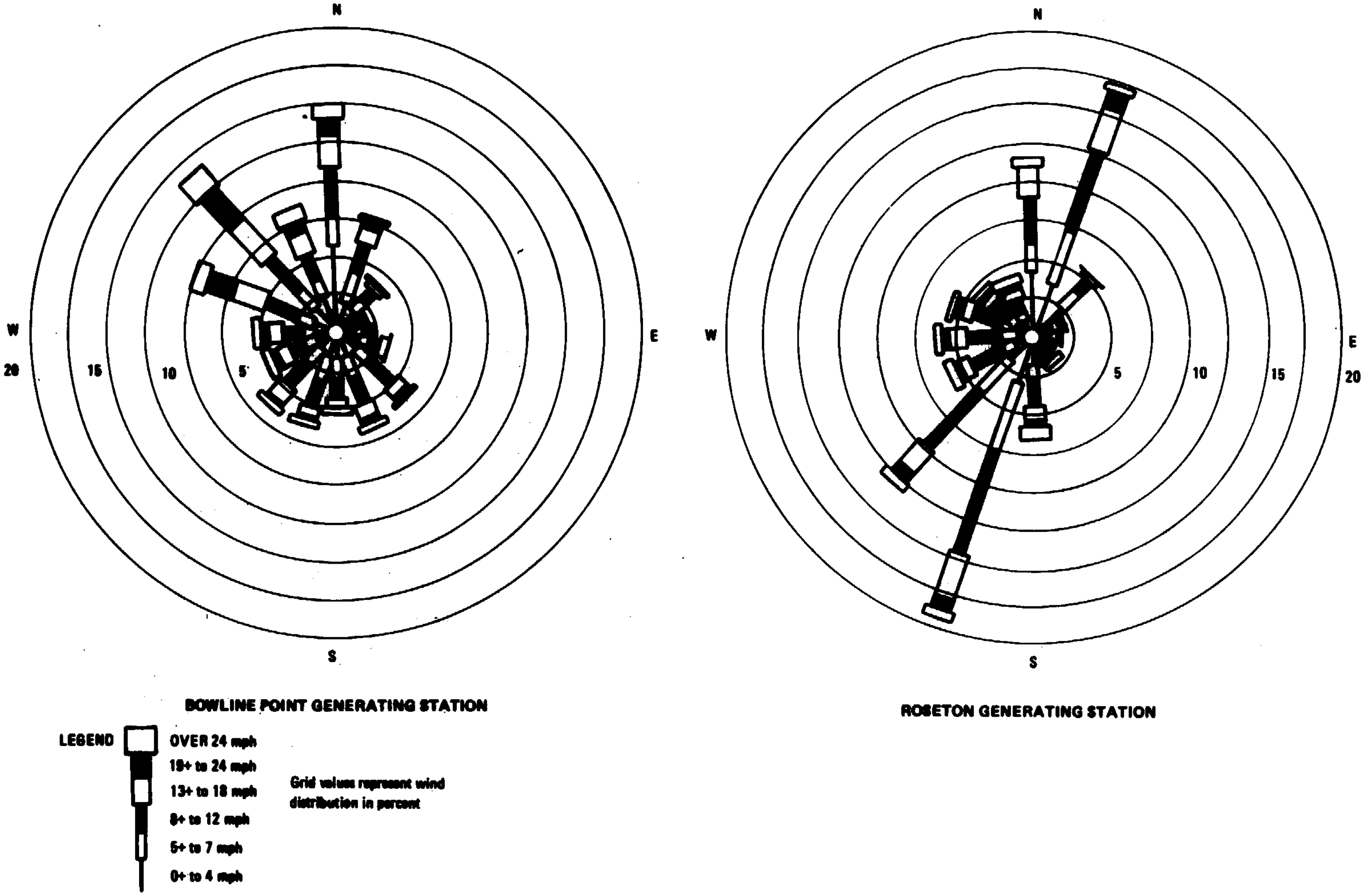


NEW YORK CITY (J. F. KENNEDY AIRPORT)
(1966-1970)

Legend
Over 24 mph
19+ to 24 mph
13+ to 18 mph
8+ to 12 mph
5+ to 7 mph
0+ to 4 mph

Grid values represent wind distribution in percent.

FIGURE 2-3
ANNUAL WIND ROSES AT SELECTED LOCATIONS IN THE STUDY AREA



BOWLINE POINT GENERATING STATION

ROSETON GENERATING STATION

Sources: Orange and Rockland, 1976; Central Hudson, 1976

FIGURE 2-4

ANNUAL WIND ROSES AT THE BOWLINE POINT AND ROSETON SITES

TABLE 2-1

QUARTERLY WIND DIRECTION FREQUENCIES BY STABILITY CLASS, JUNE 1975-MAY 1976, AT THE BOWLINE POINT GENERATING STATION

STATION	STABILITY (JUNE-AUGUST 1975)						STABILITY (SEPTEMBER-NOVEMBER 1975)					
	UNSTABLE (25.4%)		NEUTRAL (49.4%)		STABLE (25.2%)		UNSTABLE (11.2%)		NEUTRAL (55.2%)		STABLE (33.7%)	
Bowline Tower, 100-foot level	N	10.6	SSE	12.3	W	10.2	ESE	15.2	N	10.2	WNW	27.0
	NNE	10.1			WNW	33.8	NW	17.7	SSE	9.9	NW	22.9
					NW	21.2			WNW	11.0		
									NW	15.7		
	UNSTABLE (25.5%)		NEUTRAL (50.7%)		STABLE (23.8%)		UNSTABLE (10.9%)		NEUTRAL (55.2%)		STABLE (33.9%)	
Bowline Tower 200-foot level	N	11.2	SE	10.4	WNW	16.3	NW	17.4	N	9.5	WNW	9.0
	NW	10.0	SSE	13.3	NW	23.7	SSE	12.7	NNE	10.4	NW	16.8
					NNW	11.2			SSE	10.0	NNW	18.6
									WNW	10.5		
									NW	15.6		
	UNSTABLE (25.9%)		NEUTRAL (48.1%)		STABLE (26.0%)		UNSTABLE (11.8%)		NEUTRAL (55.3%)		STABLE (32.9%)	
Bowline Tower, 350-foot level	NNE	13.0	SSE	10.1	WNW	10.0	SE	16.1	N	9.4	N	9.6
					NW	13.9	NW	14.7	NNE	10.4	NW	9.0
					NNW	14.1			SSE	11.8	NNW	9.0
					N	11.8			NW	11.1		
	STABILITY (DECEMBER 1975-FEBRUARY 1976)						STABILITY (MARCH-MAY 1976)					
	UNSTABLE (5.4%)		NEUTRAL (74.1%)		STABLE (20.5)		UNSTABLE (1.2%)		NEUTRAL (65.4%)		STABLE (33.2%)	
Bowline Tower (L), 100-foot level	N	15.6	N	13.5	WNW	16.6	N	33.8	WNW	15.1	SE	15.0
	NNE	22.9	WNW	13.8	NW	26.9	NNE	33.8	NW	21.5	NW	16.6
	NE	9.4	NW	25.7			NE	14.8				
	WNW											
	UNSTABLE (4.8%)		NEUTRAL (74.7%)		STABLE (18.5%)		UNSTABLE (1.2%)		NEUTRAL (65.4%)		STABLE (33.2%)	
Bowline Tower (L), 200-foot level	N	15.7	N	10.1	NNW	17.9	N	44.4	WNW	20.9	SE	13.2
	NNE	22.9	NNE	10.8			NNE	29.6	NW	17.1		
	NE	10.0	NW	28.5								
	NW	17.1	NNW	11.5								
	UNSTABLE (4.9%)		NEUTRAL (74.6%)		STABLE (20.5%)		UNSTABLE (1.2%)		NEUTRAL (64.4%)		STABLE (34.2%)	
Bowline Tower, 350-foot level	N	31.0	N	18.0	N	9.7	N	44.4	WNW	11.2	SE	11.0
	NNE	19.0	WNW	11.8	SSW	9.4	NNE	37.0	NW	19.1		
	WNW	9.5	NW	19.5	NNW	11.1						
	NNW	11.9	NNW	9.9								

All frequencies in percent.

Source: Orange and Rockland, 1976.

TABLE 2-2

PREDOMINANT WIND DIRECTION FREQUENCIES BY STABILITY CLASS AT ROSETON GENERATING STATION, DECEMBER 1974 THROUGH FEBRUARY 1975

STATION	STABILITY					
	UNSTABLE (2%)		NEUTRAL (58%)		STABLE (40%)	
Roseton, 50-foot level	NNE	13	NNW-NNE	25	N-NNE	13
	SSW-WSW	52	SSW-WSW	36	SSW-SW	30
	NW	6	W	9	CALM	26
	CALM	9	CALM	7	OTHER*	31
	OTHER*	20	OTHER*	23		
Roseton, 280-foot level	NNE	24	N-NNE	22	N-NNE	16
	SSW-WSW	38	SSW-WSW	34	SSW-SW	37
	W-NW	18	W-WNW	17	CALM	10
	OTHER*	20	OTHER*	27	OTHER*	37

*Indicates the sum of the unlisted wind direction sectors, each less than 5% frequency.

Source: Central Hudson, 1975.

and Kinderhook and Rondout Creeks (U.S. Department of the Interior, 1972). The drainage area of the lower river is generally narrow and confined by geologic barriers such as the Berkshires and the Catskills, the Mid-Hudson ridge of the Appalachian chain, and the Palisades formation.

2.26 Steam gaging records at Green Island, immediately upstream of the Troy lock, show that the yearly average flow of freshwater in the Hudson River exceeds 13,000 cubic feet per second (National Commission on Water Quality, 1975). Monthly and yearly average flows measured at Green Island between 1972 and 1975 (National Commission on Water Quality, 1975; U.S. Department of the Interior 1976) are shown in Table 2-3 together with long-term (1918 through 1973) average flows. As the data indicate, freshwater flows vary considerably over the year with maximum flows occurring generally during the months of March, April and May. Periods of low flow usually begin in June and continue until November.

2.27 The major portion of freshwater flow enters the estuary at its head at Troy. The remaining portion consists largely of contributions by tributaries flowing into the upper reach of the estuary. Runoff from approximately one half of the river basin downstream of Green Island is gaged. The oscillating tidal flow in the estuary can exceed the flow of freshwater by a factor of 10 to 100. During each tidal cycle of 24 hours and 50 minutes, two high tides and two low tides occur, producing a mean tidal range of 4.5 feet at the Battery, 2.7 feet at West Point and 4.7 feet at the Troy Dam (U.S. Department of Commerce, 1972).

2.28 The salinity* of the Hudson River increases gradually with distance moving downstream towards its mouth (Water Information Center, 1976). In the freshwater sectors, chloride ion concentrations ranging from 6 to 30 milligrams per liter (mg/l)** may be encountered as a result of sewage and industrial discharges and runoff from adjacent lands. Values over 30 (mg/l) can be indicative of the first intrusions of seawater. Downstream of the freshwater sectors, chloride concentrations in the river increase to

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*Salinity denotes the dissolved mineral content of seawater and amounts of 34,500 milligrams per liter in the Atlantic Ocean where the Hudson River estuary discharges (Water Information Center, 1976). Six constituents make up 99 percent of the total seawater salinity. The major component is the chloride ion, which accounts for 55.0 percent; other major component ions are sodium (30.6 percent), sulfate (7.4 percent), magnesium (3.7 percent), calcium (1.2 percent) and potassium (1.1 percent).

**For percent purposes, milligrams per liter and parts per million (by weight) may be taken as equivalent units.

TABLE 2-3

MONTHLY AND YEARLY AVERAGE FLOWS OF THE HUDSON RIVER AT GREEN ISLAND FROM 1972 THROUGH 1975 AND LONG-TERM AVERAGES

update?

MONTH	FLOW (CUBIC FEET PER SECOND)				AVERAGE
	1972	1973	1974	1975	1918-1973
October	7,811	7,198	6,332	9,049	7,620
November	7,291	26,081	10,933	17,180	12,970
December	17,000	26,913	34,566	19,380	13,603
January	13,410	26,181	30,730	19,070	12,439
February	10,930	20,368	24,911	19,370	11,708
March	26,860	29,730	30,933	23,680	22,743
April	37,960	34,270	39,973	25,580	31,465
May	40,520	27,540	77,833	20,000	18,469
June	29,630	12,600	10,702	12,970	9,708
July	18,380	10,230	20,127	7,464	6,912
August	7,616	6,180	12,845	8,966	5,342
September	6,309	4,050	13,420	17,030	5,963
Yearly Average	18,643	19,278	26,110	16,610	13,172

*Water year begins in October and ends in September of the following year. For example, water year 1972 began on October 1, 1971, and ended on September 30, 1972.

Sources: National Commission on Water Quality, 1975; U.S. Department of the Interior, 1976.

values between 5,000 to 16,000 mg/l in New York City area and 15,000 to 19,000 mg/l at the outlet to New York Bay.

2.29 In broad terms, the seawater advances and recedes in the river as a wedge. Fresh and seawater at the interface remain relatively well separated when the wedge is located far downstream. Under these conditions the properties of the water at the surface and bottom differ markedly, but the front becomes increasingly diffuse as it progresses towards the middle reaches of the estuary.

extreme

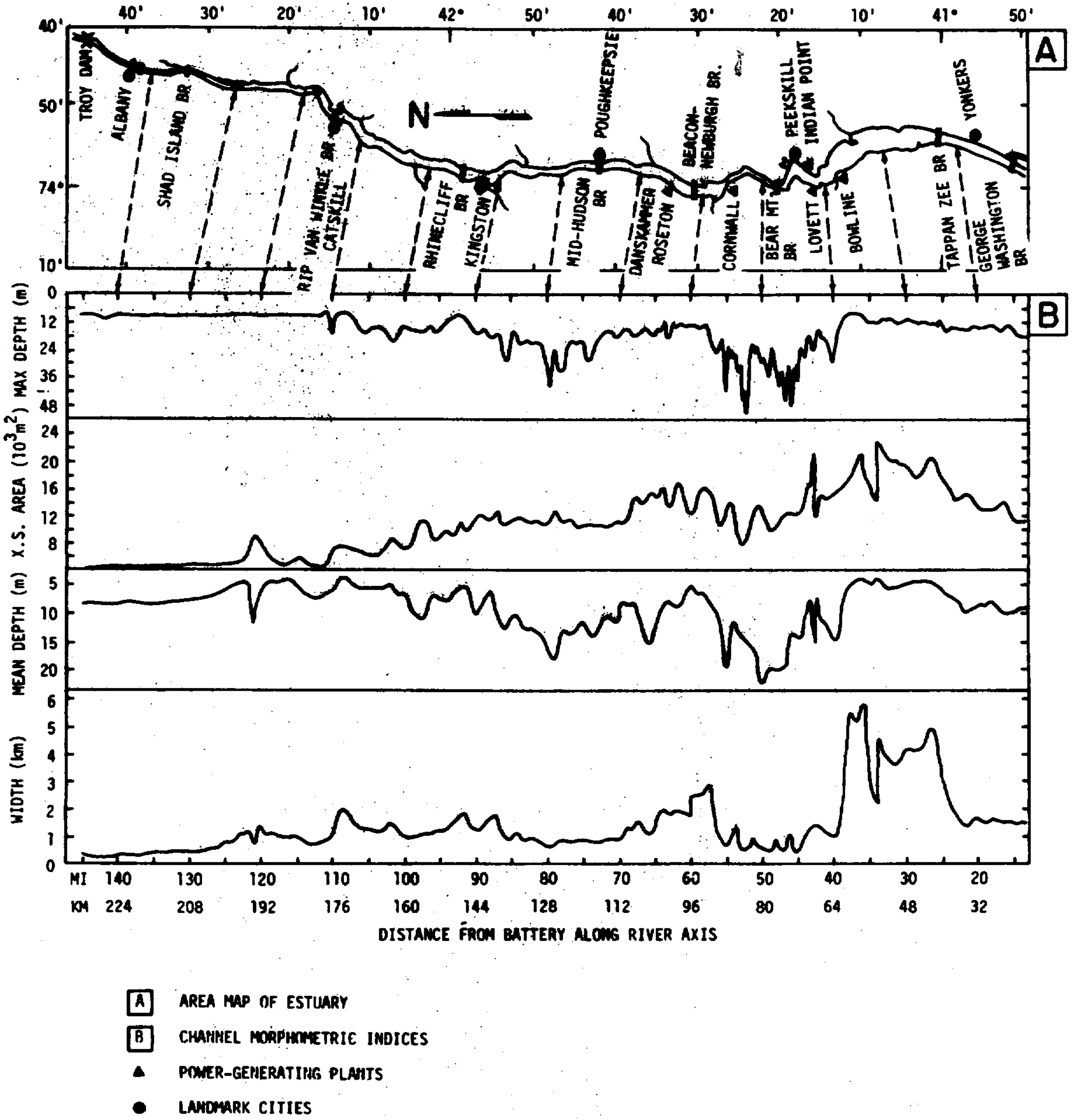
2.30 The movement of the salt front in the Hudson River estuary is influenced by several factors, principal among them being the amount of freshwater flow and the tidal surge of saline water from the ocean. The salt front oscillates with each tide in a movement, known as the tidal excursion, that may transfer the salt front upstream by as much as 8 miles on the flood tide and almost 10 miles downstream on the ebb tide. The overall mean position of the salt front can travel up or downstream in response to seasonal river flows by as much as 50 or 60 river miles. The upstream movements of the salt front are associated with higher incoming tides and diminishing upland runoffs; conversely, downstream movements are associated with increasing upland flows and lower tides.

2.31 Seasonal average profiles of chloride concentrations indicate that the salt intrusion (where the concentration of chloride ions exceed 100 mg/l) reaches Mile Point (river mile) 33 in winter, 36 in spring, 47 in summer and 48 in fall (National Commission on Water Quality, 1976). During years of normal or above normal flow, therefore, the salt front reaches the Bowline Point Generating Station at Mile Point 37.5 only in summer and fall and does not reach the Roseton Generating Station at Mile Point 65.8. The intrusion during periods of abnormally low flows may reach considerably farther upstream. For example, in the drought year of 1964, the salinity front reached as far as Mile Point 82 in the vicinity of Hyde Park.

2.32 An overview of the major morphological characteristics of the lower Hudson River is shown in Figure 2-5 and observations taken in 1974 are summarized in Figure 2-6.

Water Quality

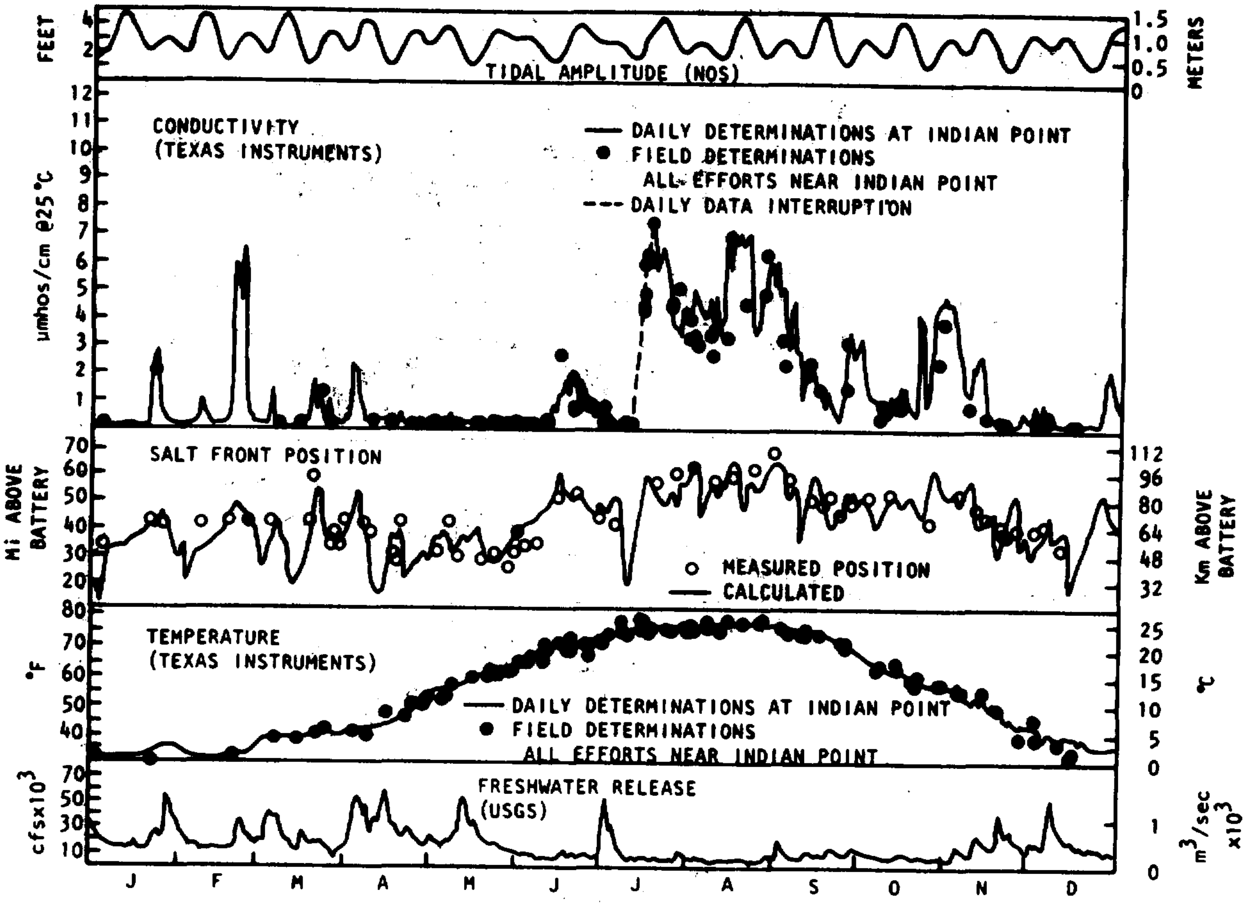
2.33 The quality of the Hudson River waters varies greatly along the estuarine portion of the river. The New York State Department of Environmental Conservation has subdivided the estuary into five segments and characterizes the quality of water in each of these on the basis of criteria developed by the Department (6 NYCRR 700-703). An overview of the classification scheme is given in Figure 2-7. As indicated, water quality in the midportion of the



Source: Texas Instruments, 1975.

FIGURE 2-5

MORPHOMETRIC CHARACTERISTICS OF THE LOWER HUDSON RIVER

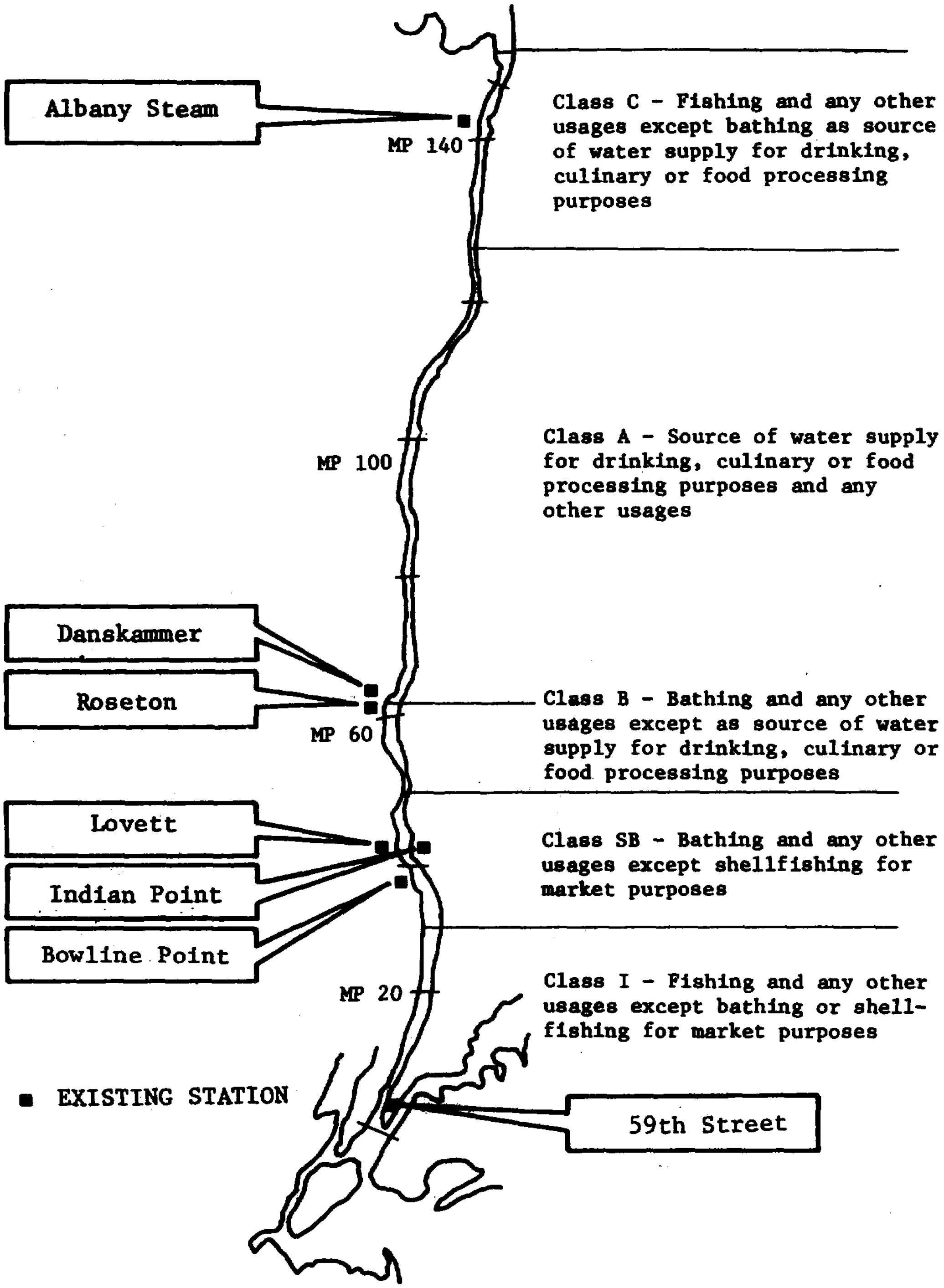


1974

Source: Texas Instruments, 1975.

FIGURE 2-6

TEMPORAL DISTRIBUTION OF FRESHWATER RELEASE,
WATER TEMPERATURE, SALT FRONT POSITION, CONDUCTIVITY, AND TIDAL AMPLITUDE
IN THE HUDSON RIVER DURING 1974



Class C - Fishing and any other usages except bathing as source of water supply for drinking, culinary or food processing purposes

Class A - Source of water supply for drinking, culinary or food processing purposes and any other usages

Class B - Bathing and any other usages except as source of water supply for drinking, culinary or food processing purposes

Class SB - Bathing and any other usages except shellfishing for market purposes

Class I - Fishing and any other usages except bathing or shellfishing for market purposes

FIGURE 2-7

OVERVIEW OF WATER QUALITY BY NEW YORK STATE STANDARDS IN THE HUDSON RIVER estuary is generally good, allowing the unrestricted use of water (including municipal supply) roughly between Mile Points 60 and 125. Water quality upstream of Mile Point 125 to the Albany area deteriorates, rendering the river unsuitable for bathing and as a source of municipal supply. Downstream of Mile Point 60 the estuary is subject to intrusion of saline water and the river becomes unsuitable for municipal supply. Progressively worsening water quality excludes the use of the river for commercial shellfishing downstream of Mile Point 50 as well as bathing downstream of Mile Point 30 through to the Battery.

update?

2.34 Municipal discharges of sewage into the river are the principal causes of poor water quality downstream of Albany and in the New York City area (National Commission on Water Quality, 1976). In spite of substantial reductions in waste loads since 1967, dissolved oxygen levels in these portions of the river fall below the critical level of 4.0 milligrams per liter* during summer and periods of extremely low flow (National Commission on Water Quality, 1976). A maximum concentration of coliform bacteria occurs in the New York City area where a count of 122,600 cells per 100 milliliters has been reported (National Commission on Water Quality, 1976). Undesirable high coliform counts are characteristic of approximately one-half of the Hudson River within the study area (National Commission on Water Quality, 1976; U.S. Council on Environmental Quality, 1976). Although the elevated bacteriological content of river waters is attributed for the most part to point sources, the contributions of stormwater runoff and combined sewer discharges are thought to be appreciable (National Commission on Water Quality, 1976).

2.35 Dissolved oxygen levels in the remainder of the estuary remain above 4.0 milligrams per liter. Although 5-day biochemical oxygen demand of the river waters is generally not high, being less than 4 milligrams per liter, the corresponding chemical oxygen demand is at a substantially higher level of 12 to 35 milligrams per liter, suggesting the presence of refractory or nonbiodegradable organic material (National Commission on Water Qualtiy, 1976).

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*A level of 4.0 milligrams per liter of dissolved oxygen is considered as a generally applicable minimum needed to ensure survival of aquatic life (U.S. Council on Environmental Quality, 1976). Other criteria adopted as benchmark values by the Council on Environmental Quality in assessing water quality trends of U.S. rivers are as follows: fecal coliform bacteria--200 cells per 100 milliliters (health protection of swimmers), biochemical oxygen demand--5 milligrams per liter, total phosphorus--0.1 milligram per liter (prevention of nuisance algae growth), and total nitrogen--1.0 milligram per liter (U.S. Council on Environmental Quality, 1976).

Nutrients

2.36 Due principally to the inflow of sewage from New York City and Albany areas, concentrations of nitrogen and phosphorus in the Hudson River estuary are often at levels higher than those generally considered to be indicative of eutrophication. Phosphorus levels exceed 0.1 milligrams per liter over almost the entire length of the river within the study area, and nitrogen levels are above 1 milligram per liter over approximately one-half that length (National Commission on Water Quality, 1976). In spite of high nutrient levels, the manifestations of eutrophic conditions are limited to occasional nearshore blooms of algae. Factors that tend to control algae productivity are the relatively short growing season and rapid flow of the river. Other factors, such as turbidity (not especially high in the Hudson River), elevated concentrations of suspended colloidal particles and abundance of organisms, act as barriers to light penetration and may further control the growth of algae (National Commission on Water Quality, 1976).

Toxic Substances

2.37 Concentrations of heavy metals in the Hudson River are generally below levels that are lethal to aquatic organisms and relatively high concentrations of iron, copper and lead have been reported (National Commission on Water Quality, 1976). The extent to which residual quantities of pesticides may be present in the waters of the Hudson River has not been determined. In view of the small portion of land devoted to agriculatural uses within the study area, pesticides are considered as a relatively minor health hazard in comparison to sewer overflows and storm runoff from urban areas (National Commission on Water Quality, 1976). The confirmed presence of polychlorinated biphenyl (PCB) compounds in the waters, sediments, and fishes of the Hudson River (New York State Department of Environmental Conservation, 1975; 41 FR 8409, 26 February 1976) has led to a ban on most commercial fishing in the Hudson River as of 26 February 1976 (6 NYCRR Section 12.19) and advice to sports fishermen to restrict the intake by individuals of fish from the Hudson to no more than one meal per week. Regulations promulgated by the U.S. Environmental Protection Agency (42 FR 6532, 2 February 1977; 40 CFR 129.105) now prohibit the discharge of polychlorinated biphenyls in liquid effluents from plants that manufacture these compounds or electrical equipment (transformers and capacitors). Nonetheless, substantial quantities of polychlorinated biphenyls remain in the river, and studies are underway to assess the severity of the problem and the means available to remove and dispose of the compounds (Kopp, 1977). There are presently no estimates of how soon the ban on commercial fishing might be partially or totally lifted or when residual quantities of polychlorinated biphenyls in the river might be substantially reduced.

Temperature

2.38 The waste heat rejected by steam electric generating facilities on the Hudson River estuary constitutes the largest component of the artificial thermal load imposed on the river (National Commission on Water Quality, 1976). Field surveys and numerical simulations (Chapter 4 and Appendix E) indicate that the temperature of the river is increased, both locally in the vicinity of the power plant and in certain portions of the estuary as a result of cumulative effects.

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Salinity

2.39 The Hudson River waters are generally characterized as fresh in the estuary south of Troy, becoming brackish below Poughkeepsie and saline below Peekskill (U.S. Department of the Interior, 1972). As previously discussed, the gradation in salinity reflects the intrusion of oceanic waters into the estuary.

Abatement of Waterborne Discharges

2.40 The anticipated reduction in point source loads under succeeding abatement levels required by the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) will largely alleviate many of the current water quality shortcomings in the lower Hudson River (National Commission on Water Quality, 1976). The law stipulates that contaminants in the liquid effluents from plants in most major industrial categories be reduced to levels that reflect the application of the "best practicable control technology currently available" by 1 July 1977 and the "best available technology economically achievable" by 1 July 1983. Municipal sewage discharges must receive secondary treatment by 1977 and best practicable treatment by 1983. The ultimate goal is to eliminate the discharge of all pollutants into navigable waterways by 1985.

2.41 Projections (National Commission on Water Quality, 1976) indicate that implementation of the 1977 requirements (application of best practicable technology) will result in large improvements in the dissolved oxygen levels in the New York harbor area. Near Albany, second treatment of municipal wastes would not be sufficient to maintain the level of dissolved oxygen above 4.0 milligrams per liter during periods of extremely low flow. In midestuary (above Haverstraw Bay and below Catskill), the 1977 requirements are expected to produce only small improvements in dissolved oxygen levels.

2.42 Point sources are the major contributors of nutient levels in the lower Hudson River. Nonpoint sources, because of limited agriculture in the basin, make relatively minor contributions (National Commission on Water Quality, 1976). Projections indicate that the 1977 and 1983 requirements will have little effect on nutrient levels in river waters. On the other hand, the elimination of all point discharges would reduce the nutrient concentrations to low values, estimated to be 10 to 20 percent of those currently prevailing (National Commission on Water Quality, 1976).

2.43 Closed cycle cooling systems, assuming these are installed at all eligible generating stations under the 1983 requirements, would substantially reduce the artificial thermal load on the lower Hudson River (Section 4 and Appendix E).

Ref settlement agreement

2.44 The 1977 requirement for secondary treatment of municipal waters is expected to result in a drastic reduction of coliform bacteria in the Hudson River. Waters would meet water quality standards applicable to swimming along the entire estuary except perhaps during periods following heavy downpours. The 1983 and 1985 requirements could lead to further reductions, but it appears doubtful that counts lower than 100 to 200 cells per 100 milliliters will be attained due to the substantive contributions of nonpoint sources (National Commission Water Quality, 1976). Concentrations of heavy metals are expected to be reduced only slightly by the 1977 and 1983 requirements, since industrial discharges represent relativley minor sources of these contaminants in comparison to storm water runoff in urban areas (National Commission on Water Quality, 1976).

Air Quality

2.45 The Hudson River estuary lies within two Air Quality Control Regions (AQCRs) established by the U.S. Environmental Protection Agency (40 CFR 81). These regions, outlined in Figure 2-8, are the New York-New Jersey-Connecticut Interstate Region and the Hudson Valley Intrastate Region. Air quality within each region is characterized by the U.S. Environmental Protection Agency in accordance with measured concentrations of sulfur oxides, particulate matter, carbon monoxide, nitrogen dioxide and photochemical oxidants. The numerical criteria given in Table 2-4 provide a basis for classifying a particular region with respect to each of these pollutants. A Class I designation denotes the lowest level of air quality, Class III the highest. The New York-New Jersey-Connecticut Region is currently characterized as Class I with respect to all five categories of pollutants. The Hudson Valley Intrastate Region is characterized as Class I for particulate matter, Class II for sulfur oxides and Class

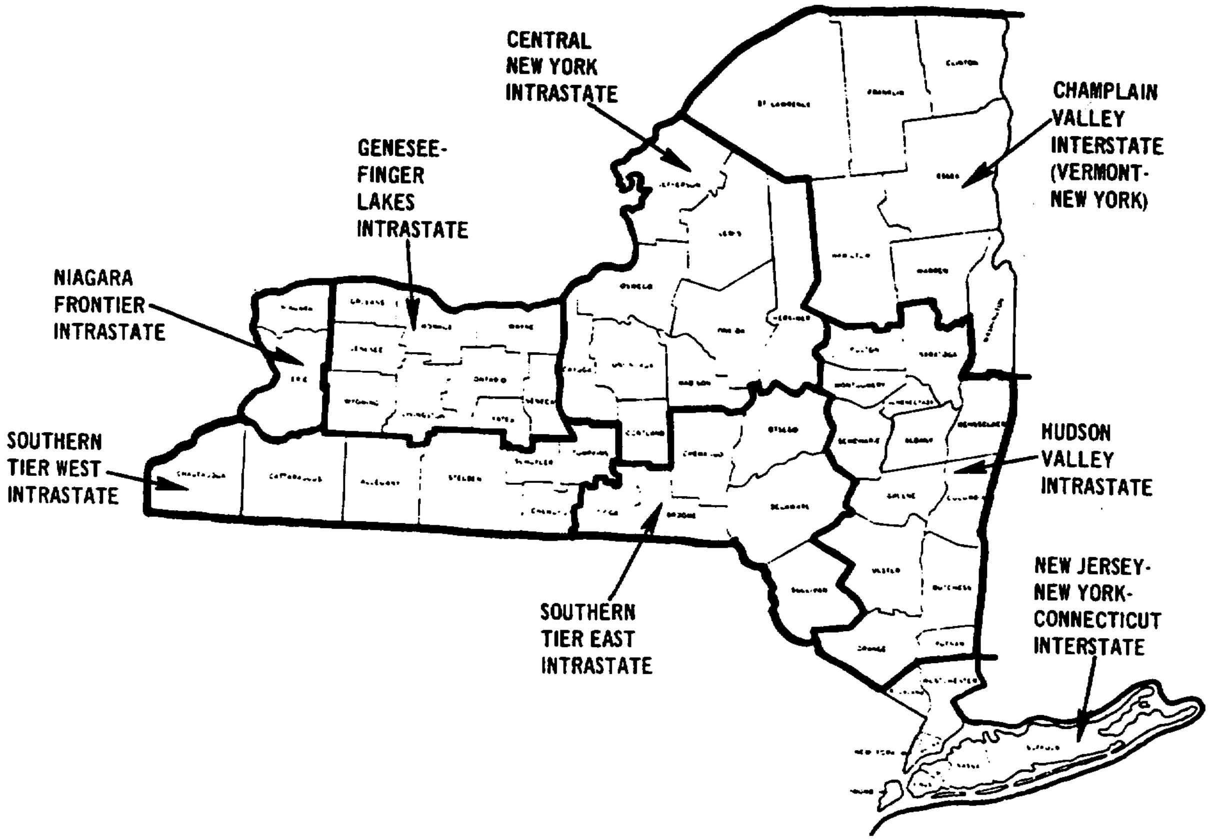


FIGURE 2-8

AIR QUALITY CONTROL REGIONS OF NEW YORK, NEW JERSEY, CONNECTICUT, INTERSTATE REGION AND THE HUDSON VALLEY INTRASTATE REGION

TABLE 2-4

POLLUTANT LEVELS FOR DETERMINING AIR QUALITY CONTROL REGION CLASSIFICATIONS

	CLASS OF REGION		
POLLUTANT	I	II	III
Sulfur oxides			
Annual arithmetic mean	> 100 μg/m^3	60-100 μg/m^3	< 60 μg/m^3
24-hour maximum	> 455 μg/m^3	260-455 μg/m^3	< 260 μg/m^3
3-hour maximum	--	$\geq$ 1300 μg/m^3	< 1300 μg/m^3
Particulate matter			
Annual geometric mean	> 95 μg/m^3	60-95 μg/m^3	< 60 μg/m^3
24-hour maximum	> 325 μg/m^3	150-325 μg/m^3	< 150 μg/m^3
Carbon monoxide			
1-hour maximum	> 55 mg/m^3	--	< 55 mg/m^3
8-hour maximum	$\geq$ 14 mg/m^3	--	< 14 mg/m^3
Nitrogen dioxide			
Annual arithmetic mean	$\geq$ 110 μg/m^3	--	< 110 μg/m^3
Photochemical oxidants			
1-hour maximum	$\geq$ 195 μg/m^3	--	< 195 μg/m^3

μg/m^3 = micrograms per cubic meter; mg/m^3 = milligrams per meter.

Source: 40 CFR 51.3.

II for nitrogen oxides, carbon monoxide and photochemical oxidants (U.S. Environmental Protection Agency, 1974). It may be well to note that the above classification system is based on data recorded at monitoring stations and, therefore, is limited in its representation of air quality within the entire region. Ambient concentrations of pollutants could be above or below those implied by the classification in isolated localities in the region.

2.46 In addition to the designation of Air Quality Control Regions, Federal regulations provide for the delineations of Air Quality Maintenance Areas (AQMAs) or areas within which violations of Federal ambient air quality standards can be expected over the decade between 1974 and 1984. The Hudson River estuary overlaps three such areas--the New York-New Jersey-Connecticut (coextensive with the Air Quality Control Region), the Mid-Hudson (extending up the valley to encompass Greene and Columbia Counties) and the Capital District (the northern end of the study area) Air Quality Maintenance Areas.

2.47 The State of New York has promulgated standards applicable to ambient air quality over the State, in accordance with provisions of the Clean Air Act. A summary of these standards together with Federal Ambient air quality standards (40 CFR 50) is given in Table 2-5. An extensive network of continuous and manual air quality monitoring systems is maintained throughout the state by the Department of Environmental Conservation, Bureau of Air Quality Surveillance (New York State Department of Environmental Conservation, 1976). In addition, monitoring systems in the New York City area and on Long Island are maintained, respectively, by the New York City Department of Air Resources and the Long Island Lighting Company (New York State Department of Environmental Conservation, 1976).

2.48 Air quality through the State of New York continues to show general improvement (New York State Department of Environmental Conservation, 1976). Since 1970, there has been a fairly consistent reduction in sulfur dioxide levels at most continuous air monitoring stations, with, for the first time in 1975, no station recording any excesses over ambient standards for sulfur dioxide. Substantial declines in annual average values of sulfur dioxide concentrations have been noted at several continuous monitoring stations in the state, a number of them within or near the study area. Among these, the Roosevelt Island Monitor in the New York city area has shown the largest decline in the state--a reduction of 73 percent between 1970 and 1975. Lesser reductions have been measured at Kingston (55 percent), Rensselaer (30 percent) and Eisenhower Park on Long Island (40 percent). The running annual averages of sulfur dioxide concentrations shown in Figure 2-9 illustrate the declining trends in measured concentrations where these have been most pronounced in the State of New York.

TABLE 2-5

SUMMARY OF SELECTED NEW YORK STATE AND FEDERAL AMBIENT AIR QUALITY STANDARDS

CONTAMINANT[1]	PARAMETER		NEW YORK STANDARDS[2]			FEDERAL PRIMARY STANDARDS		FEDERAL SECONDARY STANDARDS	
	AVERAGING PERIOD	STATISTIC	(ppm)	(µg/m^3)	LEVEL	(ppm)	(µg/m^3)	(ppm)	(µg/m^3)
Sulfur Dioxide	12 consecutive months	Arithmetic mean of 24-hour average concentrations	0.03	80	All	0.03	80		
	24 hours[3]	Maximum[4]	0.14	365	All	0.14	365		
	3 hours[5]	Maximum	0.5	1,300	All			0.5	1,300
Total Suspended Particulates	12 consecutive months	Geometric mean of 24-hour average concentrations		45	I		75		60
				55	II				
				65	III				
				75	III				
	24 hours	Maximum		250	All		260		150
	30 days[6]	Arithmetic mean of 24-hour average concentrations		80	I				
				100	II				
				115	III				
				135	IV				
	60 days[6]	Arithmetic mean of 24-hour average concentrations		70	I				
				85	II				
				95	III				
				115	IV				
	90 days[6]	Arithmetic mean of 24-hour average concentrations		65	I				
				80	II				
				90	III				
				105	IV				
Nitrogen Dioxide	12 consecutive months	Arithmetic mean of 24-hour average concentrations	0.05	100	All	0.05	100	0.05	100

ppm = parts per million by volume; µg/m^3 - micrograms per cubic meter

[1] New York State also has standards for carbon monoxide, photochemical oxidants, hydrocarbons (nonmethane), beryllium, fluorides, hydrogen suflide and settleable particulates (dustfall). Standards apply at a reference temperature of 25°C and reference pressure of 760 millimeters of mercury.

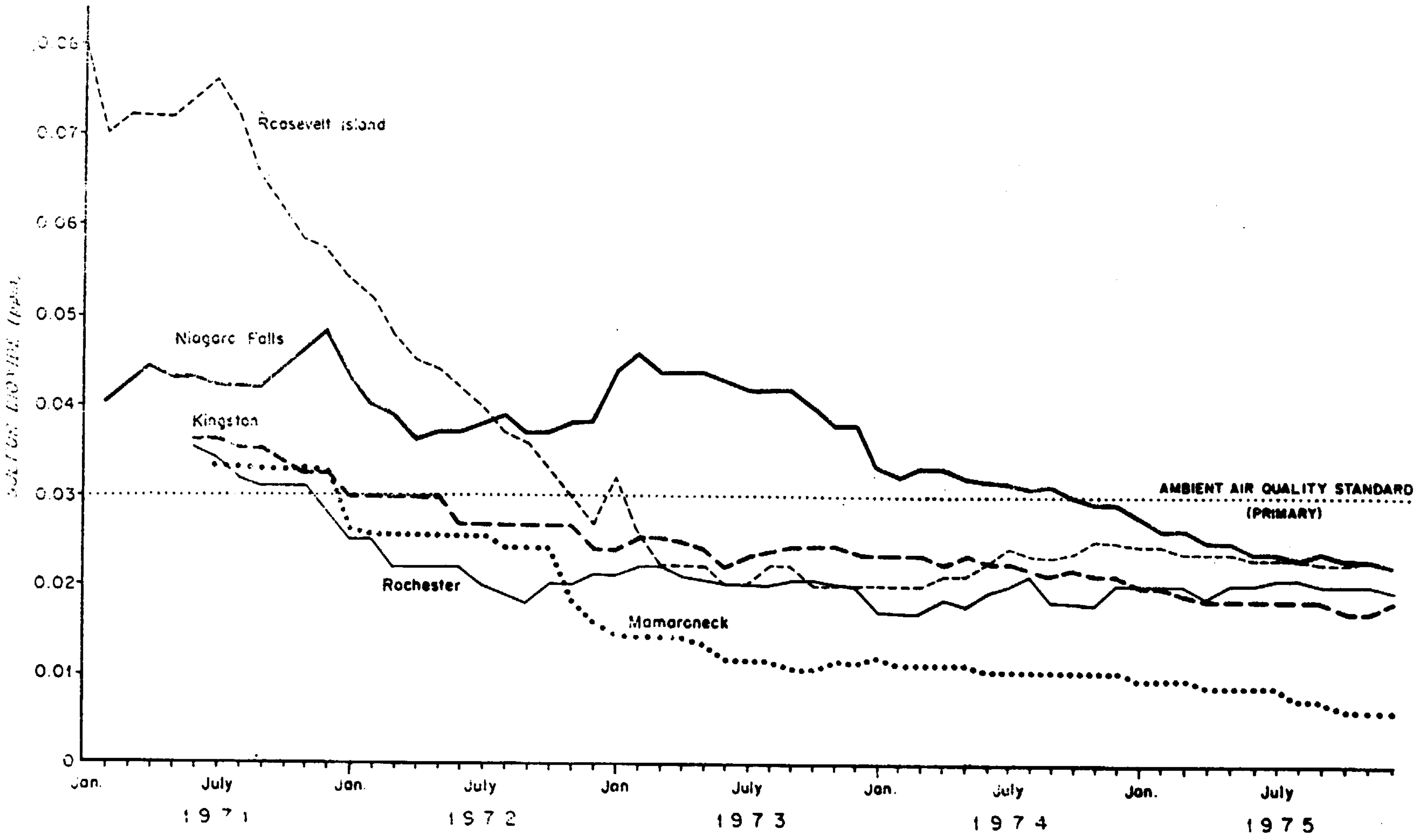
[2] In effect March 1977.

[3] Also during any 12 consecutive months. 99 percent of the values are not to exceed 0.10 ppm in New York State.

[4] All maximum values are values not to be exceeded more than once a year.

[5] Also during any 12 consecutive months, 99 percent of the values are not to exceed 0.25 ppm in New York State.

[6] For enforcement only.



Source: New York State Air Quality Report, 1976.

FIGURE 2-9

RUNNING ANNUAL AVERAGES OF SULFUR DIOXIDE TRENDS FOR 1971 THROUGH 1975

2.49 Readings of sulfur dioxide concentrations from the manual monitoring stations throughout the state generally corroborate the findings of the continuous monitoring stations (New York State Department of Environmental Conservation, 1976). The annual arithmetic means of sulfur dioxide concentrations reported by manual monitoring stations within the study area (excluding New York City and the New Jersey counties) for the years 1973, 1974 and 1975 are given in Table 2-6. None of the reported measurements in 1975 exceeds the Federal and state ambient air quality standards of 0.03 parts per million, annual arithmetic means. Relatively high values are reported in the Albany area, Kingston, Poughkeepsie and the coastal and southern portions of Westchester County. Stations in Rockland County show some of the lowest values recorded in the study area.

2.50 Observations of total suspended particulate concentrations recorded in 1973, 1974, and 1975 at manual monitoring stations within the study area (excluding New York City and the New Jersey counties) are shown in Table 2-7. The data indicate a generally improving or stable situation, with all stations except two in the Albany area reporting annual geometric mean concentrations below the Federal and state standards of 75 micrograms per cubic meter. While the information presented in Table 2-7 is inadequate to establish statistically significant trends, it may be noted that only 7 of the 43 sites reporting fail to show monotonically decreasing values from 1973 to 1975.

2.51 Fragmentary field data on airborne contaminants other than sulfur dioxide and total suspended particulates have been collected (New York Department of Environmental Conservation, 1976). Where analysis of the available data is possible (New York Department of Environmental Conservation, 1976), there are no indications that air quality is deteriorating in the study area. Instances of violations of Federal and state ambient air quality standards are generally less frequent in the data reported in 1975 than in previous years.

TABLE 2-6

ANNUAL ARITHMETIC MEAN CONCENTRATIONS OF SULFUR DIOXIDE IN THE STUDY AREA FOR 1973 THROUGH 1975 (ppm)

STATION (STATION NO.)	1973	1974	1975
Albany County			
Albany (03)	0.021	0.018	0.017
Albany (08)	0.030	0.033	
Albany (13)			0.021
Cohoes (01)		0.014	0.011
Rensselaer County			
Troy (02)		0.008	0.007
Greene County		NO DATA AVAILABLE	
Columbia County			
Hudson (02)		0.006	0.006
Philmont (02)		0.006	0.006
Ulster County			
Kingston (09)			0.011
Dutchess County			
Poughkeepsie (04)		0.012	0.017
Fishkill (01)			0.009
La Grange (01)		0.009	0.007
Orange County		NO DATA AVAILABLE	
Putnam County		NO DATA AVAILABLE	
Rockland County			
West Haverstraw (01)	0.005	0.007	0.006
Nyack (04)	0.007	0.008	0.006
Clarkstown (03)	0.002	0.005	0.003
Westchester County			
White Plains (01)	0.011	0.014	0.012
Mount Vernon (04)		0.016	0.016
Port Chester (02)	0.010	0.011	0.012
Mamaroneck (01)	0.012	0.014	0.013
Greenburg (01)	0.010	0.009	0.007
Mount Pleasant (02)	0.008	0.010	0.008
Somers (02)	0.006	0.007	0.008

Both Federal and state ambient air quality standards are 0.03 parts per million, annual arithmetic mean.

Source: New York State Department of Environmental Conservation, 1976.

TABLE 2-7

ANNUAL GEOMETRIC MEAN CONCENTRATIONS OF TOTAL SUSPENDED PARTICULATE IN THE STUDY AREA FOR 1973 THROUGH 1975 ($\mu g/m^3$)

STATION (STATION NO.)	1973	1974	1975
Albany County			
Albany (02)	110	95	79
Albany (03)	57	51	50
Albany (10)	102	76	75
Albany (13)	93	69	66
Coeymans (01)	61	44	41
Coeymans (02)	53	52	42
Colonie (03)	55	51	52
Rensselaer County			
Rensselaer (02)	74	62	54
Troy (02)	55	53	46
Castleton (01)	34	39	39
Grafton (01)	30	28	30
Greene County			
Catskill (02)	107	101	64
Columbia County			
Hudson (02)	56	58	47
Philmont (02)	29	28	29
Germantown (01)	51	46	39
Ulster County			
Kingston (04)	69	79	56
New Paltz (01)	57	61	48
Ellenville (02)	41	43	32
Saugerties (01)	70	46	43
Shawangunk (02)	50	40	31
Dutchess County			
Poughkeepsie (04)	48	58	56
Rhinebeck (02)	46	41	40
La Grange (01)	37	34	30
Orange County			
Newburgh (02)	84	73	65
Putnam County			
Brewster (01)	51	49	41
Rockland County			
West Haverstraw (01)	47	49	48
Suffern (06)	56	53	48
Clarkstown (01)	50	44	37
Orangeburg (01)	54	52	46
Westchester County			
Peekskill (01)	65	76	60
White Plains (01)	57	55	50
Mt. Vernon (04)	71	54	50
New Rochelle (02)	64	58	59
Ossining (01)	44	59	46
Port Chester (02)	51	57	42
Rye (01)	58	59	64
Mamaroneck (V) (01)	51	50	48
North Tarrytown (01)	46	53	44
Greenburgh	59	61	55
Mamaroneck (T) (01)	60	59	52
Mt. Pleasant (02)	40	45	42
Somers (02)	36	36	34
Yorktown (02)	32	37	33

Both Federal and state ambient air quality standards are 75 micrograms per meter, annual geometric mean.

Source: New York State Department of Environmental Conservation, 1976.

BIOLOGICAL RESOURCES

2.52 The biological resources of the Hudson River valley are extensive and varied. Terrestrial ecosystems include upland forests, old-field and second growth communities, agricultural lands, and suburban and urban environments. Both freshwater and marine wetland communities are found. Aquatic ecosystems include marine ecosystems at the mouth of the river near New York, medium and low-salinity ecosystems in the lower and middle estuary, and freshwater ecosystems in the upper estuary.

Upland Ecosystems

2.53 The Hudson River Valley south of Troy, New York, lies within the Oak-Chestnut Forest Region (Braun, 1950; Shelford, 1963). The chestnut has gradually disappeared with the spread of the chestnut blight and has been replaced by several species of oaks and hickories.

2.54 Because the Hudson River Valley has been extensively utilized by man for almost three centuries, past and present land use largely determines the type of vegetation that now exists. Nearly all of the forest land has been cut more than once. Since the peak of agricultural activities in the 1880s, much land has reverted to forest through natural succession. Because of the mixture of second growth forest, agricultural, and open land, the predominant animals are white tailed deer, rabbits, skunks, opossum, raccoons, squirrels, red and gray fox and ruffled grouse that adapt to this type of habitat.

2.55 Observations of the upland vegetation of the Bowline Point area prior to construction of the Bowline Generating Station are sketchy. At the time of a site visit in November 1976, willows were observed to be one of the dominant trees, with black ash, elm, and red maple also common. Animals of the area have not been surveyed. Communities in the area are likely to be made up of those species typically associated with the mixture of urban land, old field communities, tidal and nontidal wetlands, and second growth woodlands that exist.

Wetland Ecosystems

2.56 The tidal wetlands of the Hudson River Valley south of Troy consist of freshwater marshes in the northern portion and marshes adapted to the conditions of moderate salinity in the southern portion. Freshwater tidal marshlands found north of Mile Point 60 to 65 typically have higher diversity of fish species and are important nesting, resting and feeding areas for migrating waterfowl (Kiviat, 1973). Similarly, moderate salinity wetlands are known to be highly productive and to support a very diverse fauna of fish, invertebrates, and seasonally migrating waterfowl.

2.57 The abundance of some plants found in six tidal wetlands of the oligohaline Haverstraw Bay vicinity (Figure 2-10) surveyed in 1972 are compared in Table 2-8 (Lawler, Matusky and Skelly, 1975). Description of the marshes in the vicinity of the Bowline Point (Figure 2-11 and Table 2-9) prior to the construction of the power plant (Foley and Tabor, 1951; New York State Conservation Department, 1972) indicates that these marshes are similar to other marshes in the Haverstraw Bay area.

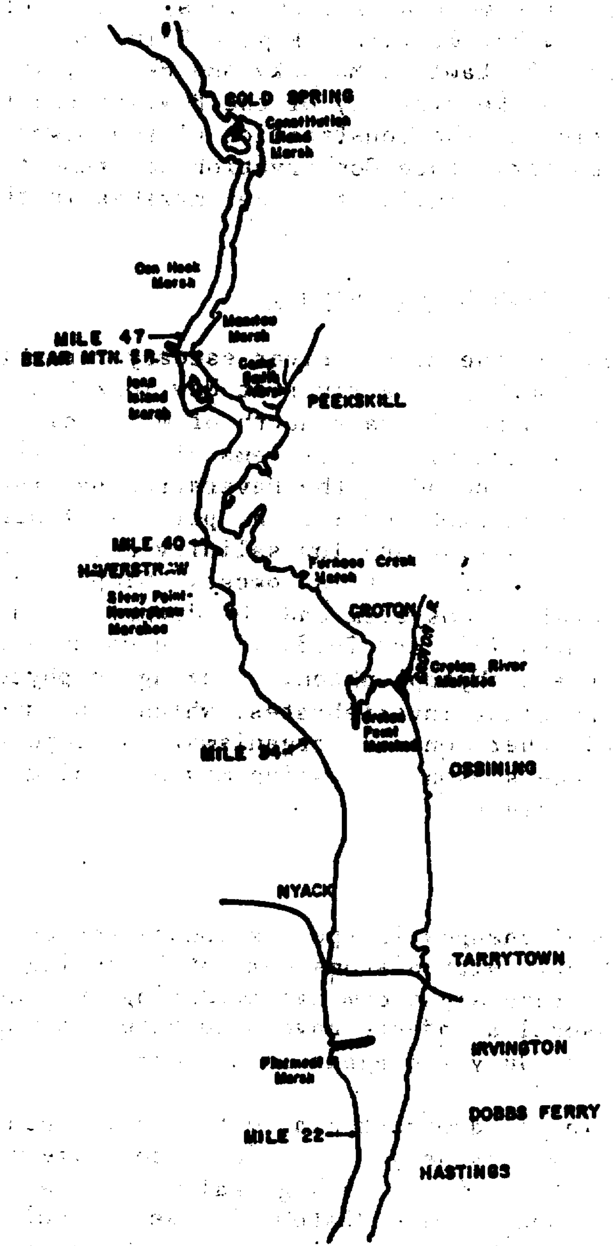
Aquatic Ecosystems of the Hudson River Estuary

2.58 The ecosystems of the Hudson River estuary range from high salinity areas at the mouth of the river at New York City to the freshwater ecosystems of the upper estuary north of Mile Point 65. In between are the mid to low-salinity ecosystems of the lower estuary and the oligohaline areas, including the Haverstraw Bay region, that experience freshwater conditions during the periods of high freshwater flow in winter and spring and low salinity conditions during summer and fall when freshwater flow is lowest. Simplified diagrams of the upriver freshwater ecosystem and the downriver saline ecosystem are given in Figures 2-12 and 2-13. In the estuary the dominant primary producers are phytoplankton. Grazing on phytoplankton are the zooplankton and other invertebrates, which, in turn, serve as food for fish and other consumer organisms. An important feature of the estuary is the seasonal spawning movement of many fish species into and out of the river.

Phytoplankton

2.59 Strong seasonal changes in species compositon occur throughout the Hudson estuary, with diatoms dominating during colder months and green and blue-green algae dominating during the warmest months. Two peaks of seasonal abundance have been noted in many studies, usually in April to July and again in October to December.

2.60 Differences in the dominant diatom type have been observed in the mid- and lower estuary. Centric diatoms are most abundant near the mouth of the estuary in high salinity areas. Dominance is shared by centric and pennate diatoms in the mid-salinity reaches of the lower estuary, while pennates are generally the most abundant in the oligohaline portions of the middle estuary, including the Bowline Point area. Because salinity tolerance varies among phytoplankton species, community dominance changes at Bowline Point seasonally with salinity.



Source: Lawler, Matusky and Skelly, June 1975.

FIGURE 2-10

TIDAL MARSHES OF THE HUDSON RIVER FROM HASTINGS TO COLD SPRING, NEW YORK

TABLE 2-8
RELATIVE ABUNDANCE IN 1972 OF SOME PLANTS IN SIX MARSHES ALONG THE HUDSON RIVER

SPECIES	PIERMONT	CROTON	HAVERSTRAW	IONA	MANITOU	CONSTITUTION
MONOCOTYLEDONS						
Gramineae (Grasses)						
Phragmites communis	xxx	xx	xx	xx	x	xx
Spartina alterniflora	xxx	xx	x	-	-	-
S. cynosuroides	xxx	x	x	-	-	-
S. patens	xxx	xx	-	-	-	-
S. pectinata	x	-	x	-	-	-
Distichlis spicata	xxx	xx	-	-	-	-
Zizania aquatica	-	x	xx	x	-	xxx
Echinochloa walteri	?	xx	xx	xx	?	xx
Leersia oryzoides	?	xx	xx	-	-	-
Cyperaceae (Sedges)						
Scirpus robustus	xx	x	-	-	-	-
S. americanus	xx	xx	xx	x	x	x
S. fluviatilis	xx	x	x	-	-	-
S. olneyi	x	xx	x	xxx	xx	xx
S. validus	xx	x	x	x	-	xx
Cyperus odoratus	?	xx	xx	?	?	?
Eleocharis calva	?	xx	?	?	?	?
Juncaceae (Rushes)						
Juncus gerardi	xx	x?	-	-	-	-
Other Monocots						
Typha augustifolia	xxx	xxx	xxx	xxx	xxx	xxx
T. latifolia	x	-	x	x	xx	x
Eleocharis parvula	?	xx	?	?	-	-
Peltandra virginica	xx	xx	xxx	xxx	xxx	xxx
Pontederia cordata	?	x	x	xx	?	xx-xxx
DICOTYLEDONS						
Broadleaf						
Lilaeopsis lineata	xx	xx	?	?	?	?
Iva frutescens	xx	-	-	-	-	-
Solidago sempervirens	x-xx	-	-	-	-	-
Atriplex patula	x	x?	-	-	-	-
Ptilimnium capillaceum	x	xx	-	-	-	-
Lythrum salicaria	xx	xx	xx	xx	xx	xx
Rosa palustris	?	x	x	x	x	xx
Cornus amomum	?	x	x	x	x	xx
Hibiscus palustris	xx	xx	x	x	?	xx
Impatiens biflora-capensis	x	x	xx	xx	x	xx
Cephalanthus occidentalis	-	x	x	x	x	x
Rhus vernix	-	-	-	xx	x	-
Pluchea purpurascens	xx	xx	x	?	-	xx
Polygonum arifolium	x	?	xx	xx	x	xx
P. punctatum	xx	xx	xx	xx	-	xx
PTERIDOPHYTES (Ferns)						
Thelypteris palustris	xx	x	xx	xxx	xxx	xxx
Onoclea sensibilis	?	x	xx	xx	xx	xx
Osmundus regalis	?	-	x	xx	xx	xx

Key:
x = incidental
xx = occasional to common
xxx = very common or large clones
\- = not present
? = questionable identification

Source: Lawler, Matusky and Skelly, June 1975.

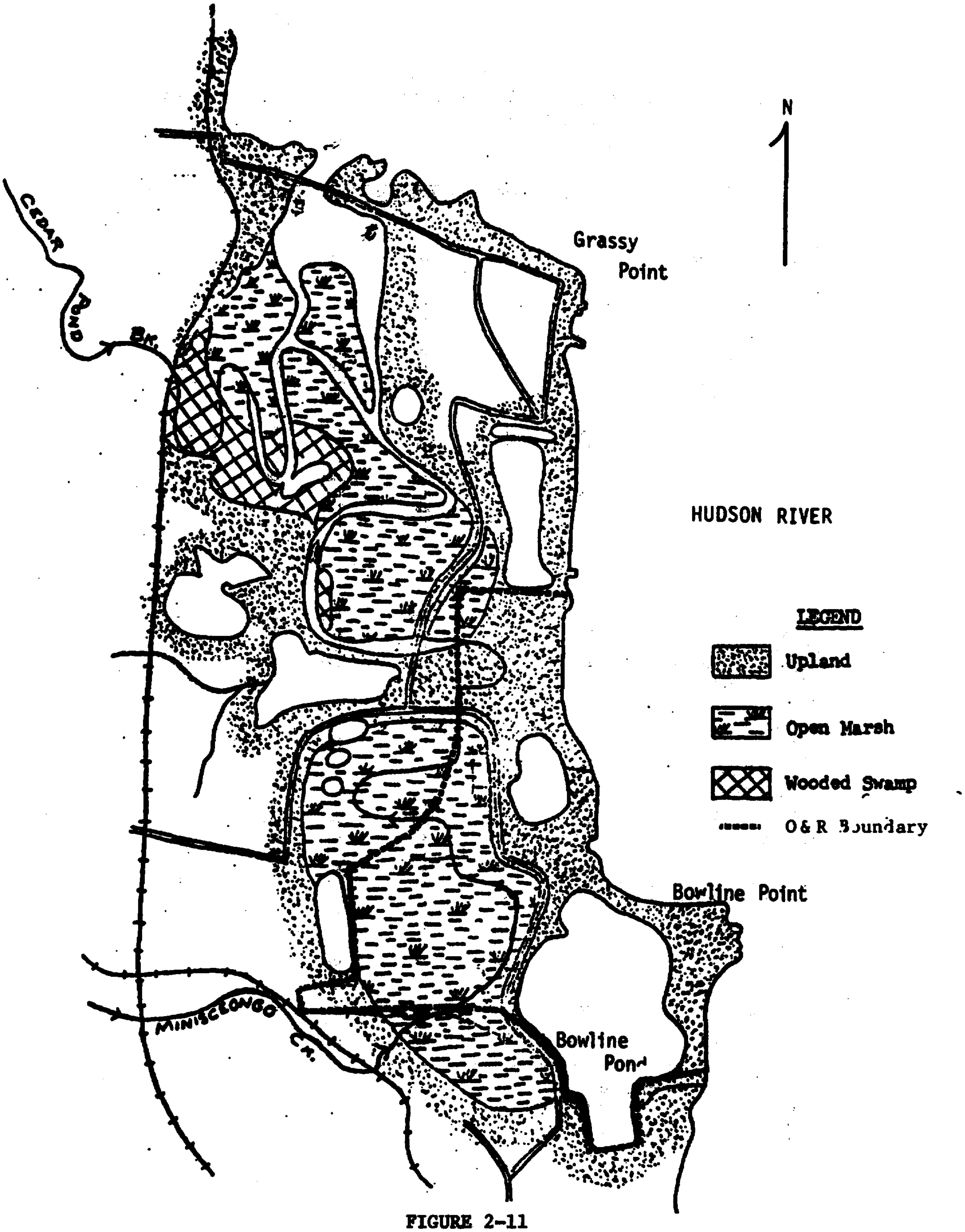


FIGURE 2-11

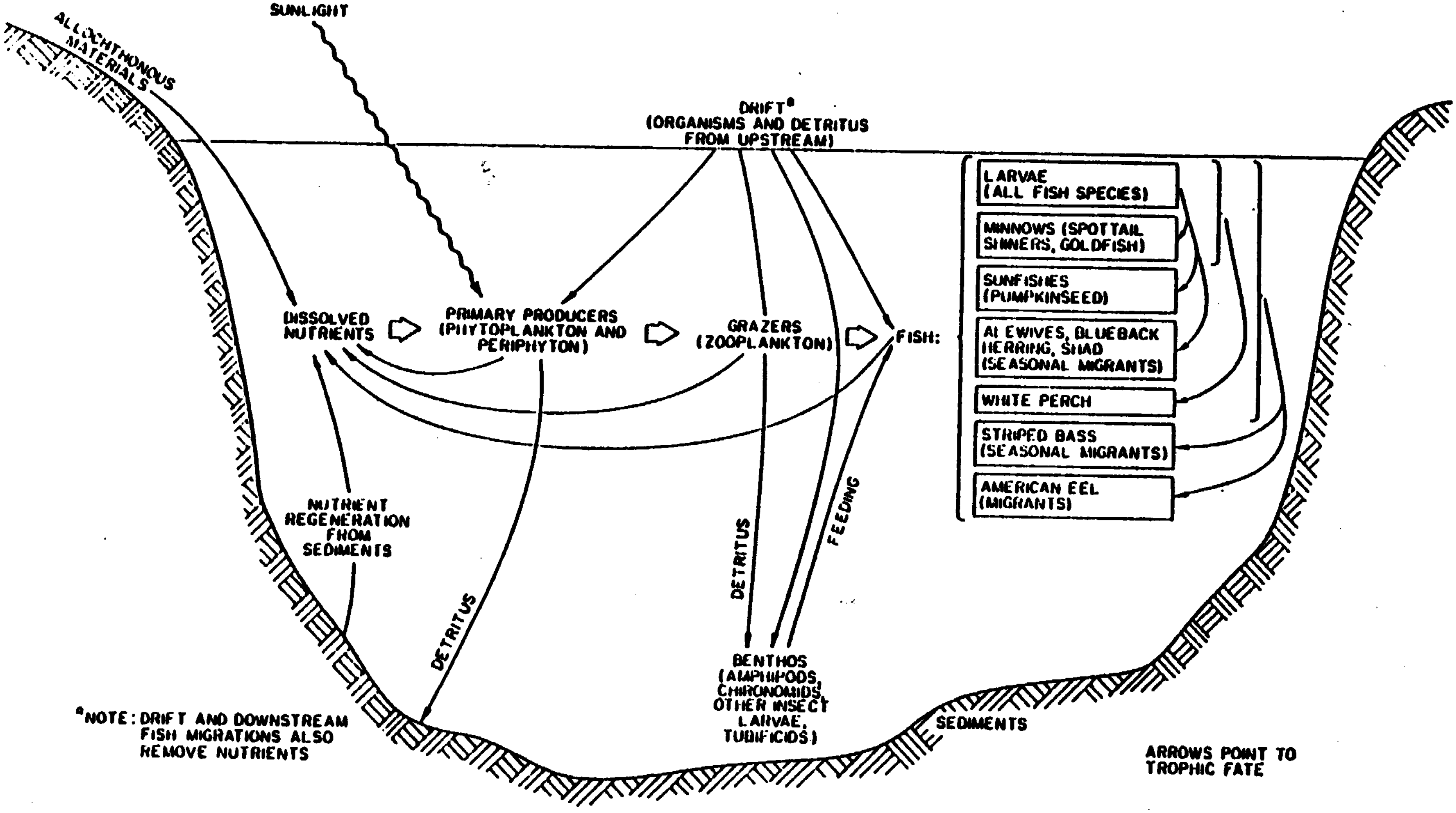
HABITAT MAP OF GRASSY POINT MARSH
BEFORE CONSTRUCTION OF THE BOWLINE GENERATING STATION

TABLE 2-9

VEGETATION OF THE GRASSY POINT MARSH

AREA STUDIED	VEGETATION	ABUNDANT	COMMON	UNCOMMON
North End of Present Property	Arrow arum			x
	Common cattail	x		
	Narrow-leaved cattail		x	
	Sweet flag		x	
	Water hemp			x
	Common jewelweed		x	
	Purple loosestrife	x		
	Swamp mallow			x
	Water parsnip			x
	Pickerelweed			x
	Common duck potato			x
	Wild rice			x
	Swamp smartweed		x	
Open Marsh Under Present Site	Common cattail	x		
	Reed grass		x	
	Common jewelweed			x
	Purple loosestrife	x		
Edge of Bowline Pond - NE	Wild celery	x		
	Sago pondweed		x	
	Common waterweed		x	
	Reed grass		x	
	Common jewelweed		x	
Edge of Bowline Pond (west)	Common coontail		x	
	Lesser bushy pondweed	x		
	Sago pondweed	x		

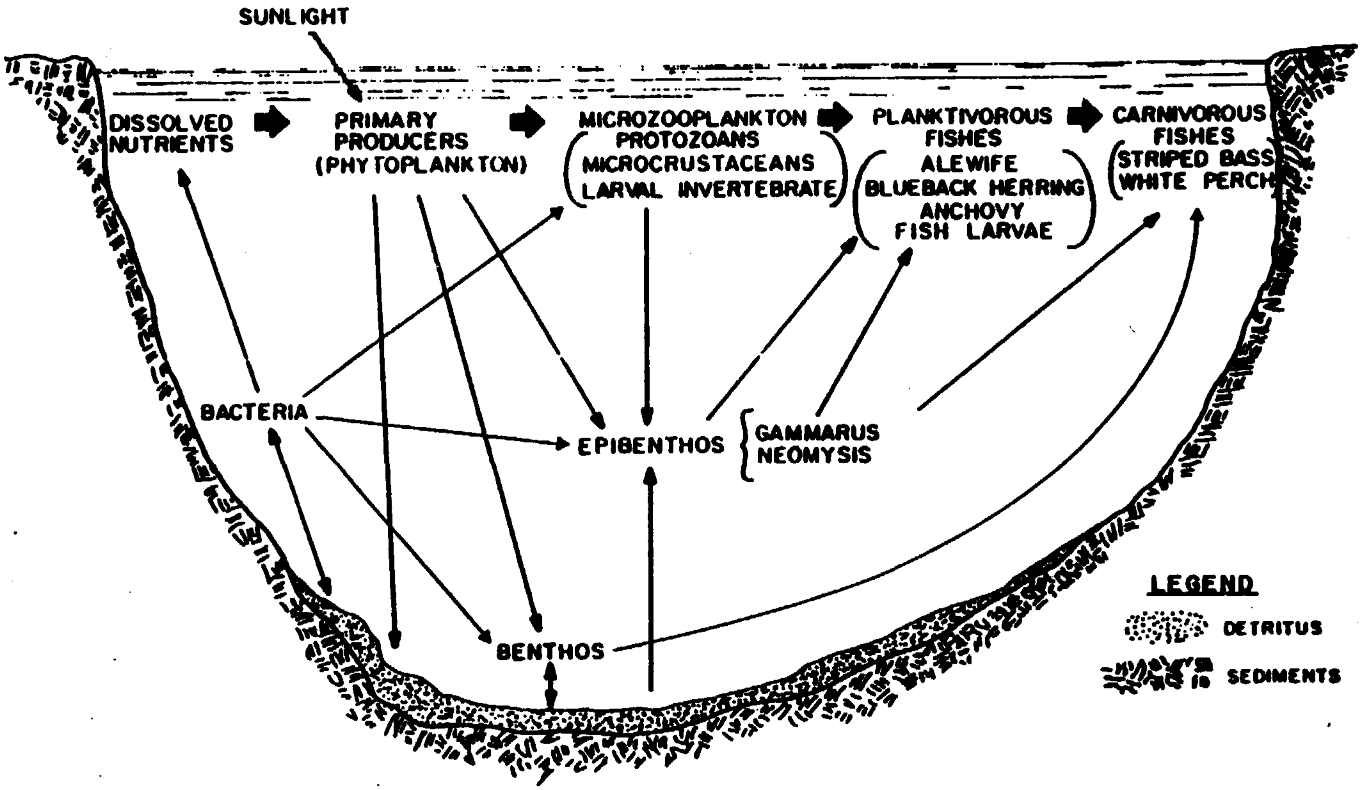
Source: Foley and Taber, 1951.



Source: U.S. Nuclear Regulatory Commission, 1976

FIGURE 2-12

SIMPLIFIED TROPHIC MODEL FOR THE HUDSON RIVER AT THE PROPOSED GREENE COUNTY NUCLEAR POWER PLANT SITE



Source: Modified from U.S. Atomic Energy Commission, 1972.

FIGURE 2-13

SIMPLIFIED AQUATIC FOOD WEB NEAR BOWLINE POINT

2.61 Total phytoplankton abundance tends to increase upstream from the mouth of the estuary. The largest standing stock of phytoplankton (measured as chlorophyll a and c) often occurs between the George Washington Bridge and Ossining during the spring-summer pulse of abundance.

Zooplankton

2.62 The zooplankton community in the Hudson River estuary is divided into the microzooplankton such as copepods, protozoans and rotifers, and the macrozooplankton such as amphipods and isopods. The community includes those species such as copepods that live their entire life cycle as plankton (holoplankton) and the planktonic larval forms of species (primarily benthic organisms) whose adult form is nonplanktonic (meroplankton).

2.63 Distribution of species along the length of the estuary varies with salinity. Mixtures of marine and salinity-tolerant freshwater species are common in the saline and brackish water portions of the estuary. Marine or brackish water organisms are rare in the freshwater portions of the estuary. A few species such as the amphipod *Gammarus* are common in all parts of the estuary.

2.64 Copepods are generally the dominant zooplankton species in the low salinity portions of the estuary, with cyclopoid forms most numerous in the winter and and calanoid forms in the summer. In the freshwater portions of the estuary, limited data suggest that Cladacerans (especially the Leptodoridae) are dominant during the summer months and copepods during the winter and spring. Rotifers are moderately abundant and may at times become numerically dominant over copepods (exclusive of copepod nauplii).

2.65 Zooplankton are most abundant during the late spring and summer in the low salinity portion of the estuary. Sometimes a smaller fall maximum will occur. Data for one year from the estuary north of Saugerties suggests that the same pattern may occur in the freshwater portion of the estuary also.

2.66 Zooplankton in the estuary tend to exhibit daily vertical migration, being most abundant in deep water during the day. Surface abundance increases greatly at night. Vertical migration is less evident among microzooplankton forms.

Benthic Animals

2.67 The salinity gradient within the Hudson River estuary is important in determining the composition of the benthic community at any point within the estuary (Ristich et al., 1977). Marine organisms adapted to relatively stable salinity conditions are restricted to a narrow portion of the estuary near the mouth. Freshwater species gradually disappear as the salinity increases downstream in the estuary. The oligohaline zone exhibits the lowest species diversity because of the rapid changes in salinity experienced as freshwater flow increases and decreases in response to seasonal rainfall patterns.

2.68 Organisms are most abundant in summer and early fall when reproduction has occurred. Biomass is greatest in fall after some growth of smaller individuals has occurred.

2.69 In the midsalinity zone, benthic community structure was initially thought to be constant from year to year (Lawler, Matusky and Skelly, 1975a). However, recent studies have shown the yearly as well as seasonal variation expected to occur in normal benthic communities (Orange and Rockland, 1977). The isopod _Cyathura polita_ is widespread, indicating low levels of pollution. Organisms characteristic of higher salinities become more prevalent in late summer and early fall when freshwater flow is lowest. The dominant organisms are annelid worms with oligochaetes more prevalent in lower salinities upstream and polychaetes more abundant toward the estuary mouth. However, at times the gastropod _Amnicola_ becomes dominant in the benthic community (Orange and Rockland, 1977). Benthic organisms are used by many species of fish as a food resource, depending on the fish species, size, and time of year. The amphipod _Gammarus_, various copepods, and dipterans are known to constitute a substantial portion of the food resource used by Hudson River fishes (Orange and Rockland, 1977).

2.70 The benthic community of the oligohaline zone has been studied most extensively in the Newburgh Bay area. Dominant benthic organisms were oligochaete worms and dipterans (insects). Numbers are greatest in spring and least in fall, except for dipterans, which are most abundant in winter and least abundant during spring. Community structure has been similar over the years studied, with year-to-year similarity greatest during spring and least during fall. The major fish food is the amphipod, _Gammarus_.

2.71 In the freshwater zone, oligochaetes and dipterans are the dominant forms. Biomass patterns are seasonal and generally related to various life cycles.

2.72 Many studies have shown the importance of benthic organisms in the diet of fish. McFadden (1977) reported that juvenile fish in the Hudson River prey upon copepods, cladocerans, amphipods, insect larvae, polychaetes, mysids, crabs, and ostracods. Adult fish consume amphipods, insect larvae, isopods, polychaetes, copepods, chironomid larvae, and shrimp. The use of food resources by fish varies with season and availability of particular food items.

Fish Eggs, Larvae, and Adults

2.73 The major migratory fish utilizing the Hudson River estuary are the striped bass (Morone saxatilis), American shad (Alosa sapidissima), blueback herring (Alosa aestivalis), Atlantic tomcod (Microgradus tomcod), alewife (Alosa pseudoharengus), ~~and American~~ eel (Anguilla rostrata). White perch (Morone americana) is an important resident species with seasonal movements in the estuary. Except for the eel, these species utilize the estuary for spawning and as a nursery area for their young. The migratory species usually spend their adult life in the downstream, high-salinity portions of the estuary or in the offshore coastal waters, moving into the middle and upper estuary to spawn. Summary life histories of the major migratory fishes of the Hudson River are given in Appendix D.

not migratory

~~tomcod~~

2.74 Information on the general spawning periods of several species and their general spawning zones is summarized in Figures 2-14 and 2-15. Although not listed in the figures, bay anchovy is an important species spawning in the mid-salinity areas of the lower estuary as well as saline waters along the Atlantic coast (Orange and Rockland, 1977). Most species are spring and summer spawners and utilize the freshwater portion of the estuary.

2.75 Yolk sac and post-yolk sac larval stages of these species move downstream at variable rates into the oligohaline zone of the salt front. As growth continues and the juveniles obtain mobility against the currents, the downstream movement continues and several species (especially striped bass) exhibit strong movement to shallow and shoal areas.

2.76 By late fall most young and adults have moved to the lower estuary. Many adults move into the Atlantic coastal waters during the winter. Young striped bass and some adults may overwinter in the lower Hudson River estuary.

Fishery Resources

2.77 The commercial fishery in the Hudson River estuary is generally confined to the lower river between Tappan Zee and Croton-Haverstraw Bay (about Mile Points 25 to 40). Some commercial fishing also takes place in the upper river from about Mile Point 70 to 120, where the primary species of value are the American shad and striped bass. The lower river fishery is primarily for shad, but striped bass, Atlantic sturgeon, white perch, and Atlantic tomcod are also

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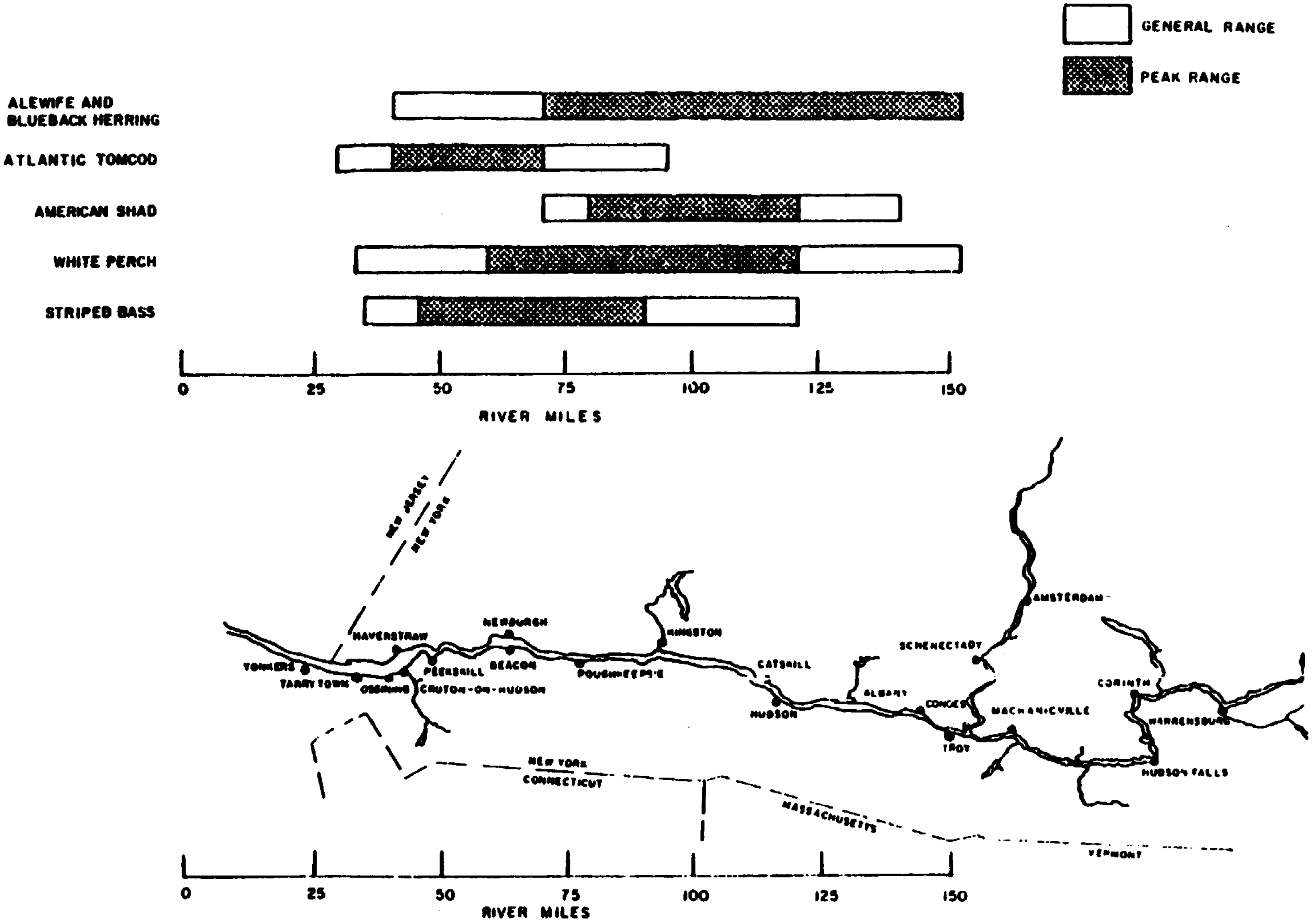
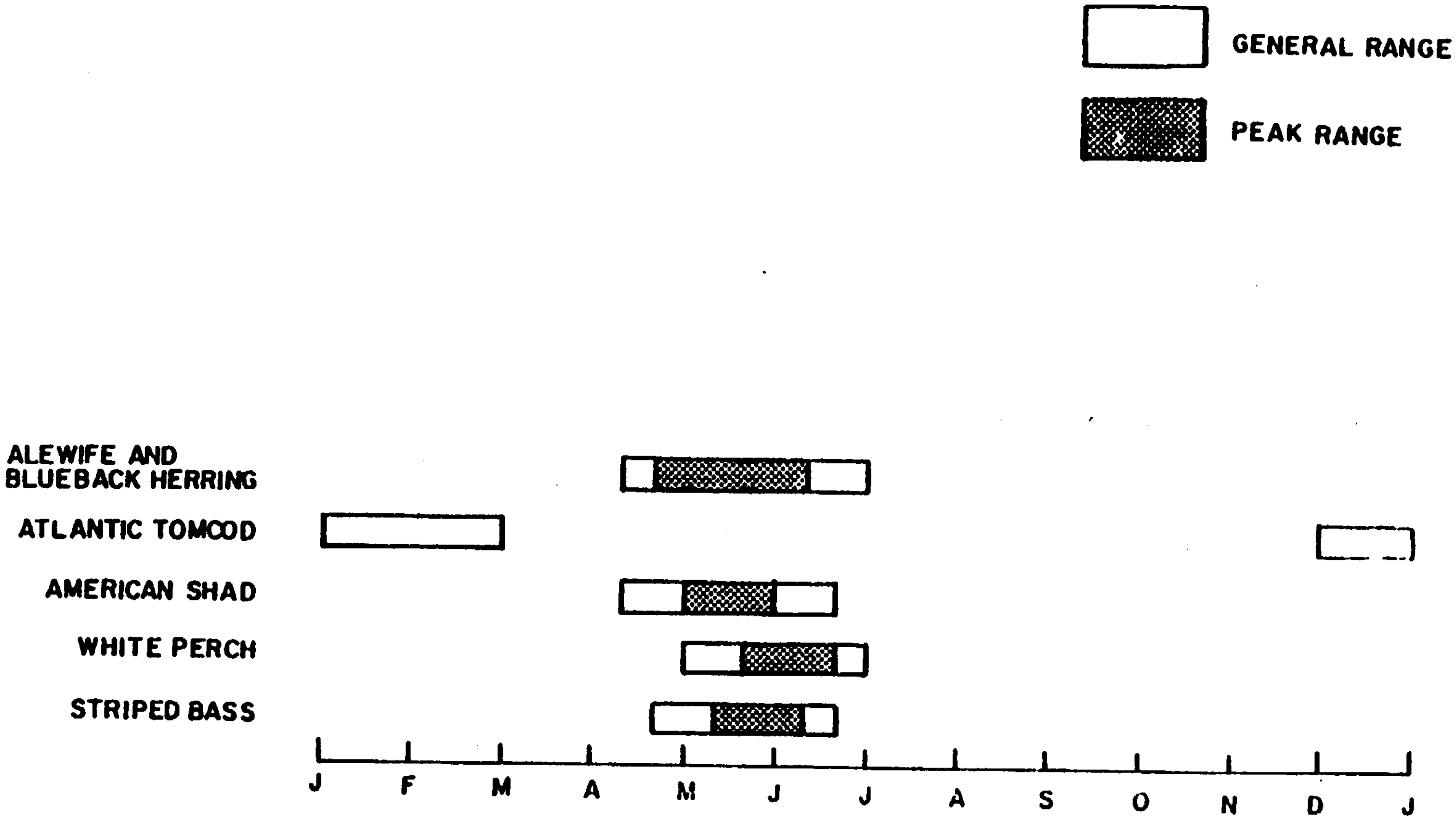


Any more recent charts?

Source: Texas Instruments, 1975

FIGURE 2-14

GENERALIZED DESCRIPTION OF SPAWNING GROUNDS OF ANADROMOUS FISH IN THE HUDSON RIVER ESTUARY



Source: Texas Instruments, 1975

FIGURE 2-15

GENERALIZED DESCRIPTION OF TEMPORAL SPAWNING DISTRIBUTION OF MAJOR ANADROMOUS FISH SPECIES collected. The fishing season is confined to the spring during the adult spawning runs.

2.78 Displayed in Figures 2-16 and 2-17 are historical trends through 1975 of Hudson River commercial landings of shad, striped bass, and alewives. While the landing statistics may vary with the intensity of fishing effort and lack precise location of capture, they provide long-term historical records.

2.79 Sport fishing is also an important use of the Hudson River's fishery resource. In 1970, the weight of the sport catch in the North Atlantic region (including New York) was 45,844,000 pounds (Deuel, 1973), compared to the commercial catch in the New England Region plus New York State of 2,780,000 pounds (U.S. Department of Commerce, 1971). However, only a portion of the North Atlantic stock is dependent on the Hudson River for spawning and nursery grounds. Striped bass spawned in the Hudson River appear to make a substantial contribution (up to 30 percent) to the fishing stocks in the North Atlantic (see Table 4-34), although presently the bulk of striped bass appear to originate in the Chesapeake Bay.

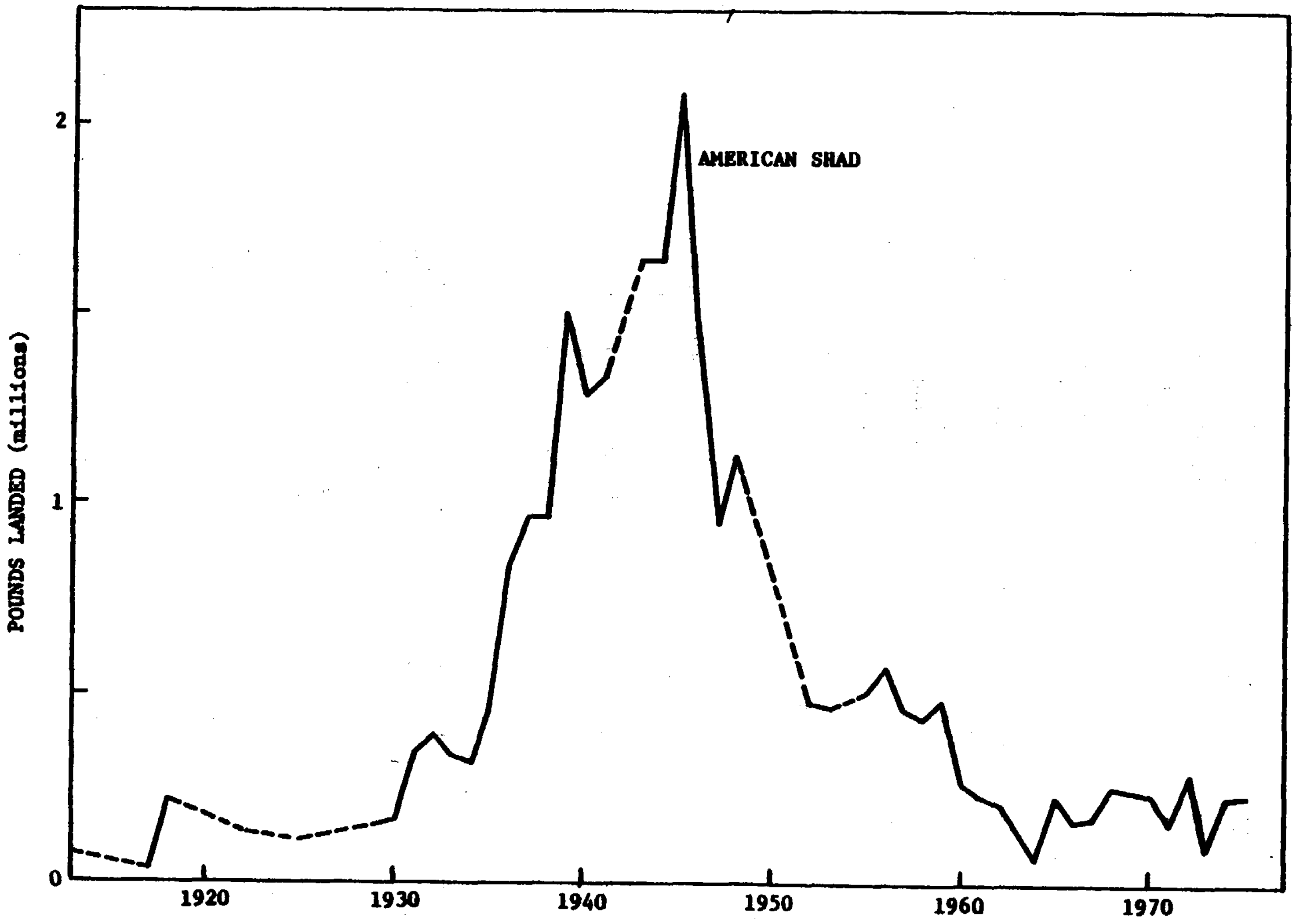
greater than what we estimate

Endangered or Threatened Species

2.80 Protected animals that are resident, extirpated, or extinct in New York State are listed in Table 2-10. In addition, all species of wildlife and plants listed by the U.S. Department of the Interior, Fish and Wildlife Service as threatened or endangered (41 FR 43340) are also considered as threatened or endangered in New York State (NYCRR Section 182.1, Title 6). However, most of these species are not indigenous to the state.

Are not Atlantics fished commercially?

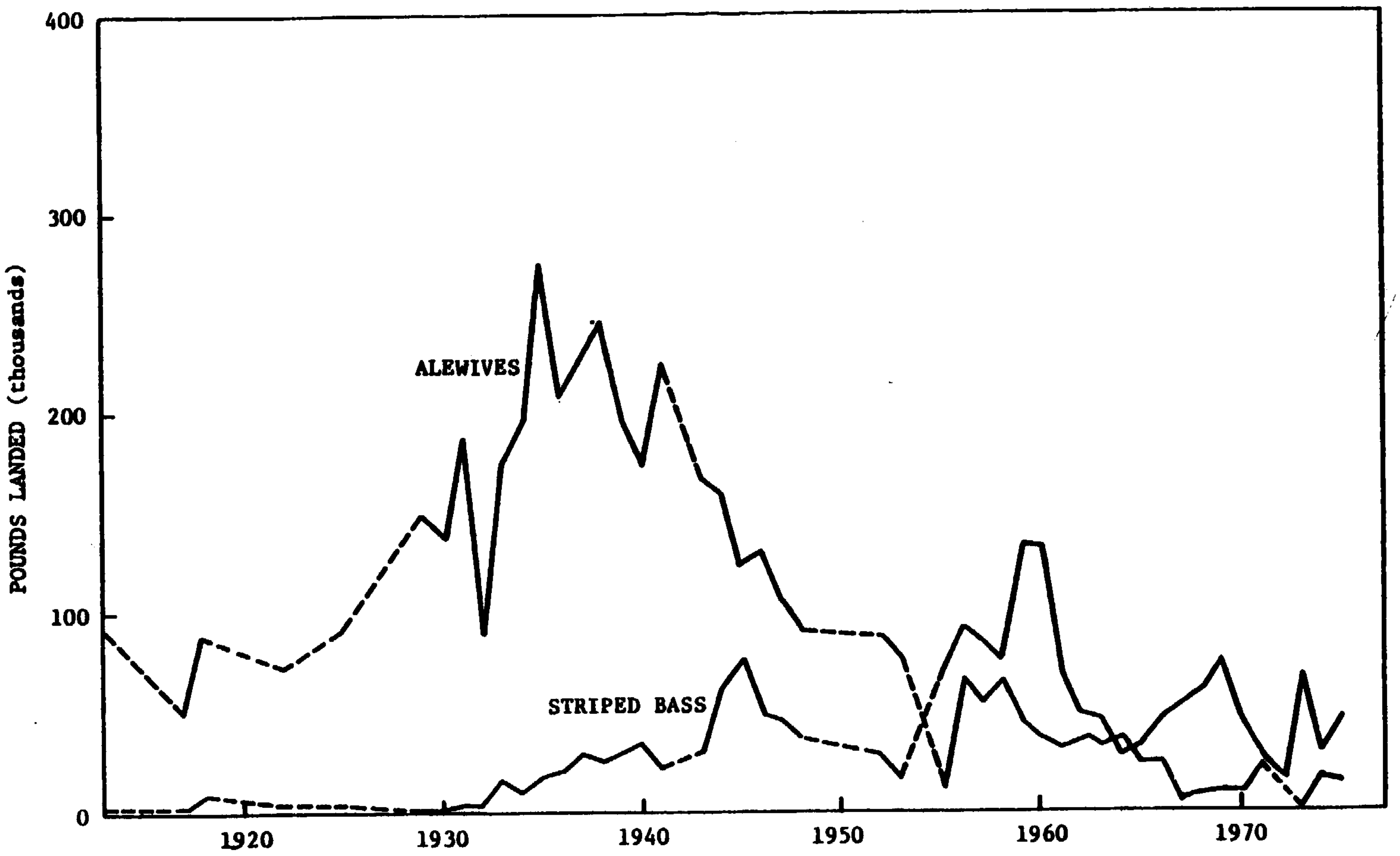
2.81 Two endangered or threatened species that potentially could be most affected by power plant operations are the shortnose and Atlantic sturgeons. Most Atlantic sturgeon present in the Hudson River during December through March are immature fish congregating in obstacle-strewn deep areas, primarily between Pollepel Island (RM57) and George Washington Bridge (RM12) (Figure 2-2). In spring, immature fish move up the river and have been observed as far north as Esopus Meadows (RM87). During summer, the immature sturgeon seek cooler, deeper waters. The distribution of juvenile Atlantic sturgeon is largely dependent on water salinity and temperature (Dovel, 1979). Spawning adults occur in the estuary from April through October. Spawning males are at least 12 years of age, weighing 12 to 105 pounds. The youngest mature female collected to date was 18 years old and weighed 72 pounds (including 8 pounds of ripe eggs). Atlantic sturgeon spawn roughly between RM36 and RM83 (see Figure 2-2), following the seasonal movement of the salt front upstream from May through July. Larvae, post yolk-sac larvae, and juvenile Atlantic sturgeon have been found generally south of Kingston (RM90)



Source: Blossom, 1976

FIGURE 2-16

COMMERCIAL LANDINGS OF AMERICAN SHAD FOR THE HUDSON RIVER VALLEY. DOTTED LINES INDICATE GAPS IN RECORD.



Source: Blossom, 1976

FIGURE 2-17

COMMERCIAL LANDINGS OF ALEWIVES AND STRIPED BASS FOR THE HUDSON RIVER VALLEY. DOTTED LINES INDICATE GAPS IN RECORD.

TABLE 2-10

ENDANGERED, EXTIRPATED AND EXTINCT WILDLIFE OF NEW YORK STATE

RESIDENT ENDANGERED SPECIES

Indiana bat[1]	Myotis sodalis
Northern bald eagel[2]	Haliaeetus leucocephalus alascanus
American osprey[2]	Pandion halieatus carolinensis
Bog turtle[2]	Clemmys muhlenbergi
Shortnose sturgeon[1]	Acipenser brevirostrum
Blue pike[1]	Stizostedion vitreum glaucum
Longjaw cisco[1]	Coregonus alpenae
Karner blue butterfly[2]	Lycaeides melissa samuelis
Cjittenango ovate amber snail[2]	Succinea ovalis chittenangoensis

MIGRANT ENDANGERED SPECIES

Southern bald eagle [1]	Haliaeetus leucocephalus leucocephalus
Artic peregrine falcon[1]	Falco peregrinus tundrius

EXTIRPATED SPECIES

American peregrine falcon[1]	Falco peregrinus anatum
Eastern timber wolf[1]	Canis lupus lycaon
Eastern puma or cougar[1]	Felis concolor cougar - possibly extinct subspecies
Elk	Cervus canadensis canadensis
Moose	Alces alces americana
Eskimo curlew[1]	Numenius borealis - possibly extinct

EXTINCT SPECIES

Gull Island vole	Microtus nesophilus
Labrador duck	Camptorhynchus labrodorius
Heath hen	Tympanuchus cupido
Carolina parakeet	Conuropsis carolinensis
Passenger pigeon	Ectopistes migratorius

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[1] Indicates that the species is on the Federal and New York State Endangered Species lists.

[2] Indicates that the species is only on the New York State Endangered Species lists.

Source: NYCRR Section 182.1, Title 6.

during May to July. In the fall, juveniles move into deeper sections of the Hudson for over-wintering and adults leave the estuary for the winter months. At this time, some juveniles, 1-6 years of age, emigrate from the Hudson River moving south along the Atlantic coast to other estuaries. There is no recreational fishery for Atlantic sturgeon at present in the Hudson River. Commercial fishing efforts have been largely ineffective in the capture of this species.

2.82 The life history of the shortnose sturgeon is not as well known as that of the Atlantic sturgeon. Shortnose sturgeon are found throughout the Hudson River south of Albany-Troy (RM150), (Dovel, 1979). During the winter, shortnose sturgeon occur in the brackish portion of the Hudson, but primarily are found in freshwater areas upstream from Kingston (RM90). Mature fish appear to move upstream in early spring to spawning grounds located between RM115-135 (see Figure 2-2). There is evidence suggesting that some fish may also spawn in the fall. After spawning, spent sturgeon move downstream into more saline areas, possibly into the Atlantic Ocean for an unknown period of time before returning to the Hudson to spawn. Larval and juvenile shortnose sturgeon (less than 5 cm total length) have been found in the Hudson River between Germantown (RM107) and Coeymens (RM 132). Older young-of-the-year have also been found in the vicinity of New Baltimore (RM130). To be conservative, it should be assumed that the 97 mile area between Haverstraw Bay (RM36) and Coeymens (RM132) represents the nursery area for larval, junvenile, and young-of-the-year shortnose sturgeon. The population of adult shortnose sturgeon in the Hudson is estimated to be about 6000 fish. However, this estimate is uncertain because of the low number of marked recaptures, and the actual size of the population could range from 2000 to 21,000.

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?
Not definitely so.

2.83 Certain species of native plants are protected by law in New York (New York Environmental Conservation Law 9-1503), making their destruction illegal. These are listed in Table 2-11. Selected species of plants from the list of endangered and threatened species of plants prepared by the Smithsonian Institution (Smithsonian Institution, 1975) are identified in Table 2-12. On the basis of habitat, those plants that could be found in the Hudson River drainage basin are included in Table 2-12. The whorled pogonia orchid (Isotria medeoloides) is the only species that appears as endangered in both the Smithsonian Institution's list and the current list of the U.S. Department of the Interior. The latter list is constantly being expanded.

Ban on Commercial Fishing in the Hudson River

2.84 On 7 August 1975, following confirmation of the presence of polychlorinated biphenyls (PCB) in the Hudson River, the New York

TABLE 2-11

NATIVE PLANTS PROTECTED IN NEW YORK STATE

COMMON NAME	**SCIENTIFIC NAME**
Green-dragon (Dragonroot)	*Arisaema dracontium*
Butterfly-weed (Chigger-flower; Orange Milkweed; Pleurisy-root)	*Asclepias tuberosa*
Bluebell-of-Scotland (Harebell)	*Campanula rotundifolia*
American Bittersweet (Waxwork)	*Celastrus scandens*
Pipsissewa (Prince's-pine; Wax-flower) Spotted Evergreen (Spotted Wintergreen)	*Chimaphila spp.*
Flowering Dogwood	*Cornus florida*
Sundew (Daily-dew; Dewthread)	*Drosera spp.*
Trailing Arbutus (Ground Laurel; Mayflower)	*Epigaea repens*
Burning-bush (Wahoo) Strawberry-bush (Bursting-heart)	*Euonymus spp.* (Native)
All ferns, including: Adder's-tongue, Azolla, Buckhorn, Cliff Brake, Curly-grass, Fiddleheads, Hart's-tongue, Maidenhair, Moonwort, Polypody, Rock Brake, Salvinia, Spleenwort, Walking-leaf, Wall-rue, Water-spangle, Woodsia. **But excluding Bracken** *(Pteridium aquilinum)*; **Hay-scented Fern** *(Dennstaedtia punctilobula)*; **Sensitive Fern** *(Onoclea sensibilis)*, **which are not protected.**	*Filices (Filicinae; Ophioglossales* and *Filicales)* (Native)
Ague-weed, Blue-bottles, Gentian (Gall-of-the-earth)	*Gentiana spp.*
Golden Seal (Orange-root; Yellow Puccoon)	*Hydrastis canadensis*
Holly (Hulver); Inkberry (Bitter Gallberry); Winterberry (Black Alder)	*Ilex spp.* (Native)
Laurel, Spoonwood (Calico-bush) Wicky (Lambkill)	*Kalmia spp.*
Lily, Turk's-cap	*Lilium spp.* (Native)
Cardinal-flower (Red Lobelia)	*Lobelia cardinalis*
All Clubmosses, including: Bear's-bed (Christmas-green, Running Evergreen; (Trailing Evergreen; Ground Pine); Bunch Evergreen; Festoon Pine (Coral Evergreen; Buckhorn; Staghorn Evergreen; Wolf's-claws); Ground Cedar (Creeping Jenny); Ground Fir; Heath Cypress	*Lycopodium spp.*
Bluebell (Roanoke-bells; Tree Lungwort; Virginia Bluebell; Virginia Lungwort; Virginia Cowslip)	*Mertensia virginica*

TABLE 2-11 (Concluded)

COMMON NAME	SCIENTIFIC NAME
American Bee-balm; Oswego Tea (Indian-heads; Scarlet Bee-balm)	*Monarda didyma*
Bayberry (Candleberry)	*Myrica pensilvanica*
Lotus (Lotus Lily; Nelumbo; Pond-nuts; Water Chinquapin; Wonkapin; Yellow Lotus)	*Nelumbo lutea*
Prickly Pear (Wild Cactus; Indian Fig)	*Opuntia humifusa* (*O. compressa, p.p.)*
All Native Orchids, including: Adder's-mouth (Malaxis); Arethusa(Dragon's-mouth; Swamp-pink;)Bog-candle (Scent-bottle); Calopogon (Grass-pink; Swamp-pink); Calypso (Fairy-slipper); Coral-root; Cypripedium (Lady's-slipper; Moccasin-flower; nerve root); Goodyera (Lattice-leaf; Rattlesnake-plantain); Kirtle-pink; Ladies'-tresses (Pearl-twist; Screw-auger); Orange-plume; Orchis; Pogonia (Beard-flower; Snake-mouth); Putty-root (Adam-and-Eve); Soldier's-plume; Three-birds; Twayblade; Whipporwill-shoe	*Orchidaceae*
Golden-club	*Orontium aquaticum*
Ginseng (Sang)	*Panax quinquefolius*
Wild Crabapple	*Pyrus coronaria*
Azalea; Great Laurel (White Laurel); Honeysuckle; Pinxter (Election-pink; Pinxter-bloom); Rhododendron (Rosebay); Rhodora	*Rhododendron spp.* (Native)
Bitterbloom (Marsh-pink; Rose-pink; Sabatia; Sea-pink)	*Sabatia spp.*
Bloodroot (Puccoon-root; Red Puccoon)	*Sanguinaria*
Pitcher-plant (Huntsman's-cup; Sidesaddle-flower)	*Sarracenia purpurea*
Wild Pink	*Silene caroliniana*
Bethroot (Birthroot; Squawroot; Stinking Benjamin; Wake-robin); Toadshade, Trillium	*Trillium spp.*
Globe-flower (Trollius)	*Trollius laxus*
Bird's-foot Violet	*Viola pedata*

Source: NYCRR 193.3, 1974 Environmental Conservation Law 9-1503 (State of New York)

TABLE 2-12

ENDANGERED AND THREATENED PLANT SPECIES OF NEW YORK STATE ON THE LIST OF THE SMITHSONIAN INSTITUTION

COMMON NAME	SCIENTIFIC NAME	STATUS	HABITAT
Whorled Pogonia orchid	*Isotria medeoloides*	E	dry woodland
Reed-Bentgrass	*Calamagrostis perplexa*	E	rocky woods
Hart's Tongue	*Phyllitis scolopendrium*	E	cool well holes
Rattlesnake-Root	*Prenanthes boottii*	T	mountains
Rockrose	*Helianthemum dumosum*	T	dry sands, barrens, open woods
Ram's Head	*Cypridedium arietinum*	T	damp woods, bogs
Small White Lady's Slipper	*Cypripedium candidum*	T	calcareous meadows, prairie
Twayblade	*Listera Auriculata*	T	alluvial banks
Orchid	*Platanthera leucophaea*	T	woodlands
Orchid	*Platanthera peramoena*	T	woodlands
Reed-Bentgrass	*Calamagrostis porteri*	T	dry woodlands
Panic-Grass	*Panicum aculeatum*	T	swampy woods
Meadow Grass	*Poa paludigena*	T	bogs, swamps
Pondweed	*Potamogeton hillii*	T	wetlands, ponds
Curly-Grass	*Schizaea pusilla*	T	low wet areas, shores
Agalinis	*Agalinis acuta*	T	sandy banks
Micranthemum	*Micranthemum micranthemoides*	T	tideflats

Sources: Smithsonian Institution, 1975; Fernald, 1970.

State Department of Environmental Conservation issued a press release advising against the consumption of fish taken from the Hudson River. On 26 February 1976, the Department imposed a ban on commercial fishing in certain portions of the Hudson River and its tributaries and the sale of fish taken in these waters.

2.85 New York State regulations (6 NYCRR 12.19) now prohibit commercial fishing in the Hudson River upstream from the Troy Dam to Fort Edward and downstream of the dam to the Battery and in all tributary waters along these reaches upstream from the river to the first falls or barriers impassable to fish. The ban applies to all fish, including American eel, except Atlantic sturgeon greater than 4 feet in length, goldfish and American shad. Regulations have been modified slightly to allow the taking of bait fish.

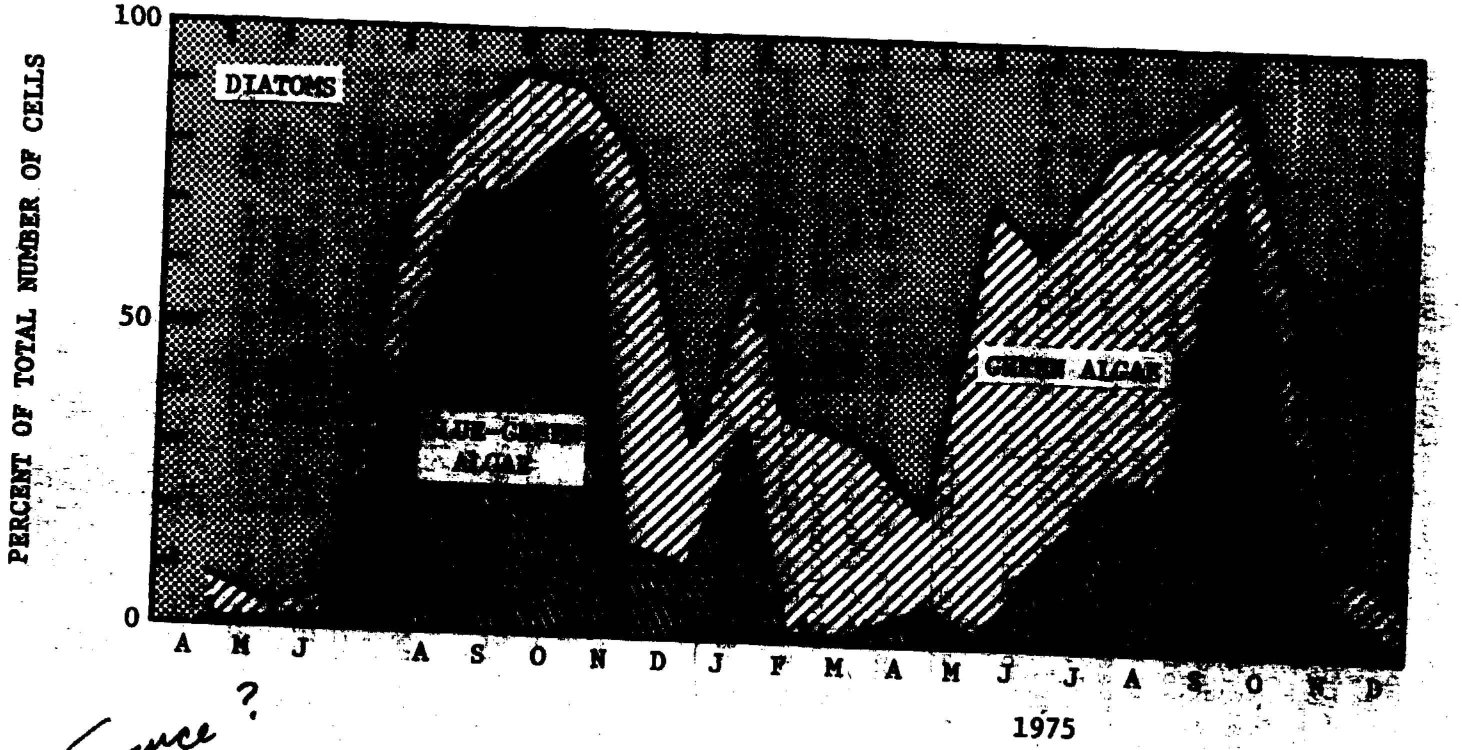
Aquatic Ecosystems of the Bowline Vicinity

2.86 The aquatic ecosystem in the vicinity of the Bowline Point Generating Station has been studied extensively over the past several years as part of the environmental studies sponsored by Orange and Rockland Utilities. The following discussion is drawn primarily from Quirk, Lawler, and Matusky (1974) and Lawler, Matusky, and Skelly (1975a, 1976a, 1978) and Orange and Rockland (1977).

Phytoplankton

2.87 The seasonal pattern of phytoplankton species succession observed in the Bowline vicinity is typical of that occurring along much of the rest of the Hudson River estuary (Figure 2-18). Diatoms, predominantly Melosira and Cyclotella, are the dominant organisms during the winter and spring. Navicula and Asterionella are also important from year to year. Green and blue-green algae predominate in the summer and fall. Among the blue-green algae, Anacystis is a dominant occurring every year, while Ocillatoria, Gomphosphaeria, and Gleotrichia are other dominants varying in occurrence from year to year. Stichococcus and Ulothrix are the dominant green algae with consistent occurrence. The occurrence of other dominant green algae such as Pediastrum, Scenedesmus, and Echallocystis varies from year to year.

2.88 Seasonal abundance of phytoplankton is characterized by a spring bloom in May or June. Usually the dominant bloom organisms are diatoms, but in 1975 it was the green algae Stichococcus. A secondary abundance peak also often occurs in the fall. Seasonal patterns of phytoplankton in Bowline Pond are usually similar to that in the Hudson River.



Source?

FIGURE 2-18

SEASONAL PATTERN OF DOMINANCE IN PHYTOPLANKTON IN THE HUDSON RIVER IN THE VICINITY OF THE BOWLINE POINT GENERATING STATION

Microzooplankton

2.89 The dominant microzooplankton in the Bowline Point vicinity are copepods, cladocerans, and rotifers. Occasionally, other species are seasonally important. Copepods are usually the most abundant species at all times of the year.

2.90 Seasonal patterns of species succession are linked to the salinity regime in the Bowline Point area, to temperature changes, and possibly to fluctuations in other environmental conditions such as nutrient levels. In the spring and early summer when river flow is still large and the waters at Bowline Point are not saline, the microplankton are dominated by cyclopoid copepods, cladocerans, and rotifers. By late summer and fall, river flow declines and the salinity rises to several parts per thousand. During this period, cladocerans and rotifers decline to low numbers and calanoids become the dominant copepod. Freshwater species return in winter as river flow increases. Spring and fall peaks in abundance have been noted at Bowline Point. The two peaks are usually copepods or rotifers.

Macrozooplankton

2.91 Amphipods, dipterans, cladocerans, and isopods are the predominant macrozooplankton in the Bowline area. Amphipods, dipterans, and isopods are also found as part of the benthic community. Cladocerans are completely planktonic.

2.92 Trends in abundance of macroplankton are similar to those of microplankton. Spring and fall peaks of amphipods (mostly *Gammarus* and *Monoculoides*) occur when freshwater flow is large. Cladocerans (*Daphnia* and *Leptodora*), another freshwater species, are also abundant in the spring. Dipterans and isopods are less abundant relative to other kinds of macrozooplankton at all times, and are less correlated with salinity changes.

Benthos

2.93 Benthic communities are similar throughout the Bowline area because of the relative homogeneity of the sediments. Molluscs, polychaete and oligochaete worms, dipterans, and crustaceans (primarily harpacticoid copepods, isopods, and amphipods) are the dominant organisms in both numbers and biomass. Organism abundance is greatest in the spring and winter, with lesser numbers in the summer. Biomass is greatest in the spring and summer and less in the fall and winter. Molluscs are represented almost exclusively by the gastropod snail *Amnicola*. Oligochaete worms were primarily *Peloscolex benedeni* and *Limnodrilus hoffmeisteri*. *Scolecolepides* and *Hypaniola* were common polychaete worms. Amphipod crustaceans are represented by *Corophium*, *Monoculoides*, and three species of *Gammarus*. Common isopod crustaceans are *Cyathura*, *Chiridotea*, and *Edotea*. *Procladius* is the common dipteran arthropod. Occurrence and relative dominance of any particular species is variable from year to year. Some seasonal variation in species composition occurs, primarily due to increases in abundance of harpacticoid copepods, isopods, and amphipods during the warmer months.

Fish Eggs and Larvae

2.94 The concentration of fish eggs in the vicinity of Bowline Point is generally low, supporting other studies indicating that major spawning areas of anadromous fishes are further upstream and downstream. Eggs of the following species have been collected in the Hudson River near Bowline Point: Atlantic tomcod, white perch, striped bass, *Alosa* spp., *Morone* spp., and the bay anchovy (Lawler, Matusky, and Skelly Engineers, 1978). During the period of February to July, fish eggs collected at Bowline Point were primarily those of the bay anchovy, which spawns in June and July (see Table 2-13). *Morone* spp. (white perch and striped bass) spawn earlier in the season during May and June and may contribute substantial numbers of eggs at these times. Egg concentrations in Bowline Pond are usually considerably less than in the river, sometimes 10 percent or less. The species composition of fish eggs in Bowline Pond is similar to that observed in the river proper (Quirk, Lawler and Matusky, 1974).

these are S.B. + W.P.

2.95 Seasonal abundance and species composition of larvae vary with the spawning patterns of the dominant species in the estuary. Three peaks of larval abundance generally occur (see Figure 2-19). The larvae of Atlantic tomcod (a winter spawner) appear in greatest numbers in late winter and early spring. Another peak of larval concentration occurs in May through early July composed primarily of striped bass, white perch, and species of *Alosa* (alewife, blueback herring, and shad). Bay anchovy larvae become numerous during mid-June to mid-September. Other species contribute a relatively small percentage of larvae to the total throughout the warmer months. Mean monthly fish larvae abundance in Bowline Pond generally ranges between 60 percent and 10 percent of abundance at Bowline Channel (Lawler, Matusky and Shelly Engineers, 1976).

Fish

2.96 The fish community of the Bowline Point vicinity is typical of the oligohaline areas of the Hudson River Estuary. Atlantic tomcod, white perch, hogchoker, bay anchovy, striped bass, alewife, and blueback herring are the dominant members of the community. Actual abundance and relative dominance of each species is

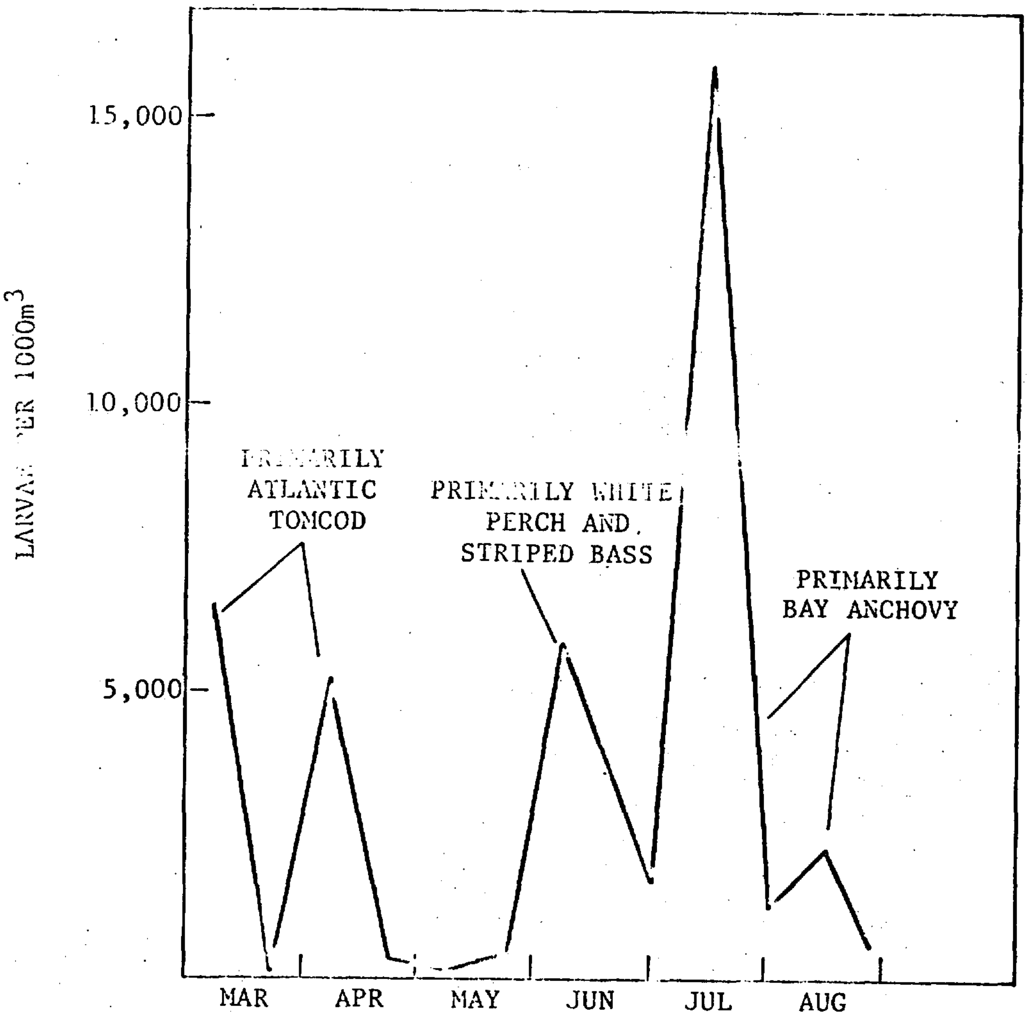
TABLE 2-13

FISH EGG ABUNDANCES IN THE HUDSON RIVER AT BOWLINE POINT DURING 1977

	FISH EGG ABUNDANCE (no./1000m^3)	
DATE	TOTAL[a]	BAY ANCHOVY
24 February	0	0
08 March	0	0
15 March	0.3	0
29 March	0	0
31 May	18	18
02 June	2.7	2.3
06 June	14.0	1.3
08 June	4.3	4.3
13 June	784.3	784.3
16 June	3767.0	3765.0
20 June	56.3	26.3
23 June	24.3	24.3
27 June	536.3	536.3
30 June	4.0	4.0
05 July	0	0
12 July	7159.3	7159.3
19 July	301.6	301.6
26 July	1121.6	1121.6

[a] Averaged from 3 sampling transects, at all depths and sampling times.

Source: Lawler, Matusky, and Skelley, 1978; Table IV-4.



Source: Lawler, Matusky, and Skelly (1978), Table UB-23

FIGURE 2-19
SEASONAL VARIATION IN DENSITIES OF FISH LARVAE
AT BOWLINE POINT

variable from year to year depending on such factors as year class strength, seasonal river flow, and salinity in the Bowline area. Overall seasonal abundance is greatest in the river from mid-summer through mid-fall. Seasonal abundance of fish species in the Bowline area is consistent with the life cycle of each species.

2.97 The species composition in Bowline Pond is different from that in the river. Blueback herring, redbreast sunfish, banded killifish, and white perch are the dominant species.

Aquatic Ecosystems of the Roseton Vicinity

2.98 The aquatic ecosystem in the vicinity of the Roseton Power Generating Station has been studied extensively as part of environmental studies sponsored by Central Hudson Gas and Electric. The following discussion is drawn from Quirk, Lawler, and Matusky (1973) and Lawler, Matusky, and Skelly (1975b, 1976b), and Central Hudson Gas and Electric (1977).

Phytoplankton

2.99 The seasonal pattern among the phytoplankton observed at the Bowline point generating station of diatom dominance in the winter and spring shifting to green and blue-green algae in the summer and fall is also the typical pattern in the vicinity of Roseton. Common diatoms include *Coscino-discus*, *Cyclotella*, *Melosira*, *Asterionella*, *Navicula*, and *Nitzschia*. *Cyclotella* and *Melosira* are the most frequent dominants with the others varying in importance from year to year. The dominant green algae are *Eudorina*, *Pediastrum*, *Scenedesmus*, *Tetrastrum*, *Ulothrix*, *Panadorina*, and *Mougeotia*. Frequently occurring blue-green algae include *Oscillatoria*, *Chroococcus*, *Aphanocapsa*, *Microcystis*, *Lyngbya*, *Merismopedia*, and *Anacystis*. The particular dominants are variable from year to year among the green and blue-green algae.

Microzooplankton

2.100 Copepods, cladocerans, and rotifers are the dominant microzooplankters in the Roseton vicinity. Abundance is similar to that at Bowline Point but seasonal shifts in species at Bowline Point related to salinity are not observed at Roseton because of the predominantly freshwater regime. Copepod nauplii and rotifers are often the most numerous organisms during all but the dryest years. *Bosmina* is the dominant cladoceran. *Important rotifers are Keratella*, *Brachionus*, and *Nothulca*. No distinctly repeating seasonal pattern of species composition is usually evident.

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Macrozooplankton

2.101 Amphipods (Gammarus sp.), dipteran larvae, and Leptodora (a cladoceran) are the most abundant macrozooplankters in the vicinity of the Roseton Generating Station. One or two peaks of abundance occur, usually in the early summer and/or fall. The microplankton exhibit daily vertical migration, being more evenly distributed throughout the water column during the night and concentrated at greater depths during the day.

Benthos

2.102 Tubificid oligochaete worms and dipteran larvae dominate the benthic community in the Roseton vicinity. Isopods, amphipods, decapods, turbellarians, polychaetes, leeches, arachnids, molluscs, and other insect groups are less common. Limnodrilus hoffmeisteri is the dominant oligochaete. L. udekemianus, L. profundicola, Stylaria Fossularia, Vejdovskyella intermedia, V. Comata, and Aulodrilus pluriseta are found less frequently. The most frequently occurring dipteran larvae are the chironomids Coelotanypus sp. and Polypedilum sp. Other groups, such as biting midges (Ceratopognidae) and the phantom midge (Chaeoborus sp.) are sometimes seasonally abundant.

2.103 Community structure and organism abundance generally has been similar at all sites sampled in the estuary near Roseton, probably because of the relatively homogeneous sediment characteristics of the area. Occasionally, abundance at one or two stations would be statistically different from other stations. No clear overall trends in seasonal abundance of total macrofauna and seasonal species composition are evident.

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Fish Eggs and Larvae

2.104 Two major periods of fish larvae abundance occur in the Roseton vicinity (Figure 2-20). The first is in late winter and consists of Atlantic tomcod. During the second period, striped bass, white perch, and Alosa sp. larvae appear in greatest numbers in late May, June and early July, usually peaking in June. Other species most numerous in June were tessellated darter (Etheostoma olmstedi) and cyprinids (Carassius auratus, Cyprinus carpio, Notropis spp.). Other species identified were rainbow smelt (Osmerus modax), sunfish (Lepomis spp.), yellow perch (Perca flavescens), killifish (Fundulus spp.) and sturgeon (Acipenser spp.). The bay anchovy (Anchoa mitchilli) is present in low numbers in July and August.

2.105 Limited data on fish egg abundance and occurrence is available for Roseton. Sampling during 1974 showed low numbers of eggs in May and June, peaking in early May at an average

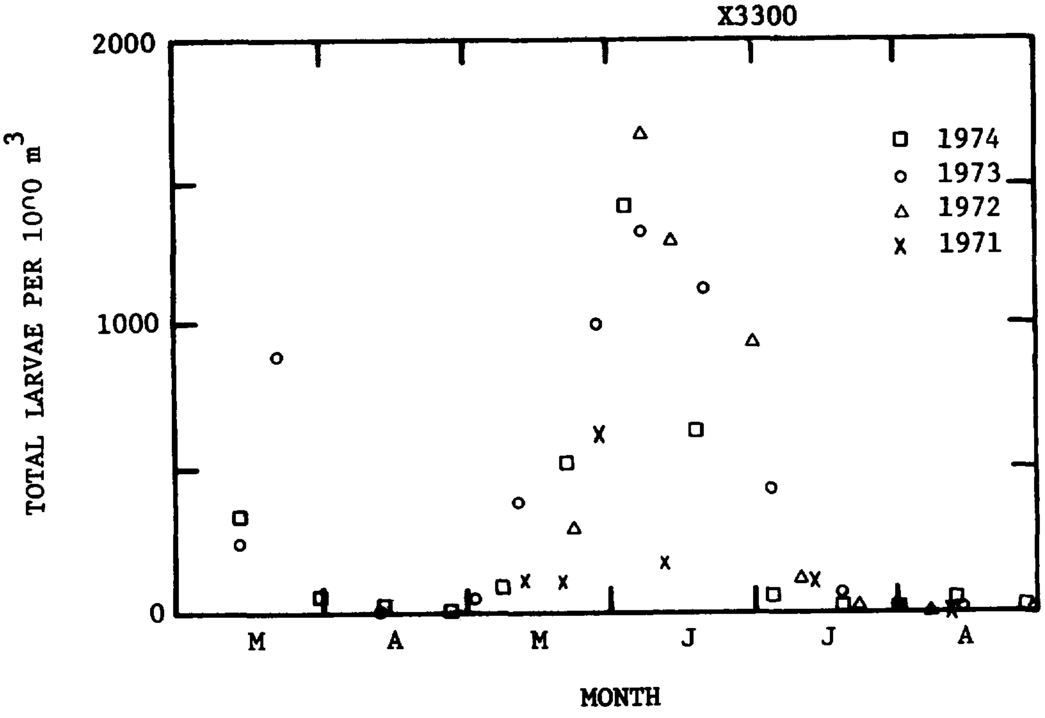

FIGURE 2-20

OCCURRENCE OF FISH LARVAE IN THE HUDSON RIVER
AT THE ROSETON POWER GENERATING STATION

concentration of 45.7 eggs per 1000 cubic meters of water. Other samples contained less than five eggs per 1000 cubic meters.

Fish

2.106 In any single year, 8 or 10 species usually make up the majority of the fish community in the vicinity of Roseton as measured by trawling, gillnetting, seining, and trapping. White perch and blueback herring usually account for 35 percent or more of the catch. Other species are more variable in their relative abundance from year to year. Atlantic tomcod is the most variable, representing 34.5 percent of the catch in 1972, but only 3 and 7.7 percent in 1973 and 1974, respectively. Alewife, American shad, spottail shiner, golden shiner, other *Alosa* species, brown bullhead, pumpkin-seed sunfish, striped bass, bay anchovy, hogchoker, white catfish, and American eel have all represented more than 1 percent of the catch in at least one sample year. Striped bass are usually caught in relatively low numbers, representing 1.9 percent (1972), 4.6 percent (1973), and 0.9 percent (1974) of the catch over the sample period.

2.107 Total fish abundance is greatest during spring and summer. Species and age makeup of the fish community change throughout the year as adults migrate up and down the estuary and as young of the year grow and move in and out of the area.

HUMAN RESOURCES

2.108 The Hudson River estuary, as defined in the present study, supports a population (1975) of 11,400,000 (U.S. Department of Commerce, 1976a). The area* encompasses all or portions of three Standard Metropolitan Statistical Areas; namely, New York, Poughkeepsie, and Albany-Schenectady-Troy.

Population

2.109 Population statistics pertaining to the Hudson River estuary are given in Table 2-14. As the data indicate, the counties in the southernmost portion of the study area (Bergen and Hudson Counties in New Jersey and the City of New York) together with Westchester County account for a population of almost 10 million or 87 percent of the population within the entire study area. Albany and Rensselaer Counties, with a combined population of nearly 500,000, account for a further 4 percent. The balance of 9 percent of the population is distributed among the remaining seven counties which, in terms of geographical extent, make up approximately two-thirds of the study area. Population is not evenly distributed over these counties. There are notable concentrations in Rockland, Orange, and Dutchess Counties and low populations in Putnam, Columbia and Greene Counties. Population densities vary greatly over the study area, ranging from the extremely high densities of New York City (more than 25,000 persons per square mile) and Hudson County, New Jersey (12,400 persons per square mile), to a low of 59 persons per square mile in Greene County. Rockland County has a population density of 1,415 persons per square mile.

2.110 Population has been increasing in portions of the study area and decreasing in others. The number of residents increased substantially between 1970 and 1975 in Putnam (22.4 percent) and Greene (15.3 percent) Counties. Ulster (9.7 percent), Orange, Rockland and Columbia (7.0 percent) Counties experienced moderate growth over the same period. Growth was somewhat lower in Dutchess County (5.6 percent) and the population in Albany and Rensselaer Counties remained virtually stable (0.7 percent growth in both counties). Population decreased over the 1970-1975 period in New York City, Bergen and Hudson Counties in New Jersey and Westchester County. New York City and Hudson County both registered losses in excess of 4 percent. The population of New York City, the New Jersey Counties of

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*Counties adjacent to the Hudson River from the Albany-Troy area south to the Battery in Manhattan. For present purposes, the City of New York (Bronx, Kings, New York, Queens, and Richmond Counties) are treated as a single entity within the study area.

TABLE 2-14

POPULATION STATISTICS FOR THE REGION OF THE HUDSON RIVER ESTUARY

COUNTY	SQUARE MILES	1975 POPULATION	POPULATION DENSITY (Persons per Square mile)	POPULATION CHANGE (Percent) 1960-1970	POPULATION CHANGE (Percent) 1970-1975
Albany	526	288,900	549	-2.7	0.7
Rensselaer	665	153,600	231	-0.6	0.7
Greene	653	38,200	59	3.7	15.3
Columbia	645	55,100	85	4.6	7.0
Ulster	1,141	155,000	136	10.8	9.7
Dutchess	813	234,800	299	14.8	5.6
Orange	833	242,500	291	11.1	9.4
Putnam	231	69,400	300	65.6	22.4
Rockland	176	249,100	1,415	52.4	8.4
Westchester	443	877,000	1,980	2.5	-1.9
Bergen, N.J.	234	871,900	3,726	6.5	-2.8
Hudson, N.J.	47	582,800	12,400	-7.7	-4.1
New York City (1)	300	7,567,800	25,226	16.4	-4.2

Sources: U.S. Department of Commerce, 1976a.

(1) Bronx, Kings, New York, Queens and Richmond Counties.

Bergen and Hudson, and Westchester County decreased during the 1970 to 1975 period; New York City and Hudson Counties both registered losses in excess of 4 percent. Population in New York State as a whole declined by 0.7 percent over the same period, compared to a loss of 0.3 percent sustained in the decade between 1960 and 1970 (Rand McNally, 1976).

2.111 The population in Rockland County increased from 136,803 in 1960 to 229,903 in 1970, an overall increase of 68 percent (U.S. Department of Commerce, 1973). Growth moderated to an overall increase of 8.4 percent between 1970 and 1975, to reach 249,100 for 1975.* Population in the Town of Haverstraw, one of five townships forming Rockland County, increased from 16,632 in 1960 to 23,311 in 1970, an overall increase of 40 percent (U.S. Department of Commerce, 1976a). The population reached an estimated** 30,260 in 1975, representing a further increase of 30 percent.

Socioeconomic Profile

2.112 The Hudson River estuary is area one of the nation's principal centers of industrial, commercial and financial activities. Employment in the area (1970), as indicated by the selected socioeconomic statistics presented in Table 2-15, is oriented heavily towards the manufacturing industries. Trade (wholesale and retail) and government services represent the region's other major employment sectors. The volume of trade (retail sales) in the area is related to the distribution of population and is greatest in the southern and northern portions of the area, least in Columbia, Greene and Putnam Counties. Median family incomes in 1969 were lowest in Columbia and Greene Counties; the median income in Putnam County was considerably higher, due to its large suburban population.

2.113 The portion of land area devoted to farming declined in each of the counties in the study area between 1969 and 1974. The relative decrease was largest in the southern portion of the estuary, where the acreage in farming represented a relatively minor use of the land. Despite the decline, farms still (1974) occupy substantial portions of Columbia (37 percent), Orange (28 percent), Dutchess (27 percent), Rensselaer (26 percent) and Albany (23 percent) Counties, the noted dairying and fruitgrowing region of the Hudson River. Much of Greene and Ulster Counties lies in the Catskill Mountains, and relatively small portions of these counties are suitable for farming.

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*The Planning Board of Rockland County estimates the population figure to be 260,000; established by communication with the Board on 16 February 1977.

**Estimated by the Planning Board of Rockland County; established by communication with the Board on 16 February 1977.

TABLE 2-15

SOCIOECONOMIC CHARACTERISTICS(1)

COUNTY	BASIC TRAINING AREA (2)	TWO LARGEST EMPLOYMENT SECTORS, PERCENT EMPLOYED	SALES VOLUME(2) ($1,000's)	MEDIAN FAMILY INCOME	LAND IN FARMS(3)	
					PERCENT OF LAND, 1974	PERCENT CHANGE 1969-1974
Albany	Albany/Schenectady/Troy	Gov't, 29/Trade, 20	1,010,539	$11,015	23	-11
Rensellaer	Albany/Schenectady/Troy	Manuf, 23/Gov't, 21	223,637	10,084	26	-10
Greene	Albany/Schenectady/Troy	Manuf, 22/Gov't, 22	17,673	8,552	16	-14
Columbia	Albany/Schenectady/Troy	Manuf, 26/Trade, 17	27,403	8,709	37	-12
Ulster	Poughkeepsie/Kingston	Manuf, 29/Trade, 19	128,553	9,808	11	-11
Dutchess	Poughkeepsie/Kingston	Manuf, 33/Gov't, 19	232,506	11,658	27	-14
Orange	Newburgh/Middletown	Manuf, 23/Gov't, 20	235,261	10,128	28	-4
Putnam	New York City	Manuf, 20/Gov't, 17	15,468	11,995	5	-51
Rockland	New York City	Manuf, 22/Gov't, 21	293,537	13,751	1	-63
Westchester	New York City	Manuf, 21/Trade, 20	3,080,290	13,774	5	-15
Bergen, N.J.	New York City	Manuf, 30/Trade, 22	3,983,359	13,591	2	-50
Hudson, N.J.	New York City	Manuf, 35/Trade, 17	1,540,304	9,695	-	-
New York City(4)	New York City	Manuf, 19/Trade, 19	59,196,380	18,609	-	-

Sources: (1) U.S. Department of Commerce, 1973.
(2) Rand McNally, 1976.
(3) U.S. Department of Commerce, 1976b.
(4) Bronx, Kings, New York, Queens and Richmond Counties.

2.114 The median family income among residents of Rockland County in 1969 was $13,751, second only to the median income of Westchester County ($13,774) within the study area and considerably higher than the median income of $10,609 in New York State as a whole (U.S. Department of Commerce, 1973b). In 1970, there were 60,359 occupied housing units in the county, 70.4 percent of which were occupied by the owner (U.S. Department of Commerce, 1973b). The civilian labor force numbered 86,555 with 83,436 being employed. The breakdown (percent of labor force) of employment by employing sector in 1970 was:

Manufacturing	21.8
Wholesale and Retail Trade	19.2
Services	6.8
Educational Services	10.5
Construction	6.3
Government	20.8
Craftsmen and Foremen	12.6

The Bureau of the Census classified 59.7 percent of the labor force as white collar workers, made up of 32.4 percent professionals and 27.3 percent sales personnel.

Land Use

2.115 Selected statistics on land use for the counties forming the study area (except the City of New York) are given in Table 2-16. The information is derived from a survey conducted in 1958 and updated in 1967 by the Soil Conservation Service, (U.S. Department of Agriculture, 1967; 1970). Although the information may be outdated, it is the latest available set of data that applies consistently and is presented here to provide an overview of the urbanization pattern on the Hudson River estuary.

2.116 The data in Table 2-16 indicate that the New York counties of Putnam, Rockland and Westchester are almost completely urbanized. Bergen and Hudson Counties in New Jersey are heavily urbanized, although a sizable portion of Bergen County is forested. The remaining counties of the study area are less urbanized, and one-half or more of the area in each county is primarily forested. Greene and Ulster Counties, in particular, are heavily wooded and unurbanized. Catskill Park, a state reserve, occupies major portions of these counties. The major Federal land holding in the study area is the West Point U.S. Military Academy in Orange County.

2.117 A land use plan has been developed for Rockland County (County of Rockland, 1973). The northwestern portion of the county is occupied largely by the Harriman State Park. Residential

TABLE 2-16

LAND USE STATISTICS, EXCLUDING CITY OF NEW YORK

COUNTY	LAND AREA, ACRES	URBAN AND BUILTUP		FEDERAL NON-CROPLAND ACRES	INVENTORY ACREAGE(1)	PERCENT OF INVENTORY ACREAGE(2) IN		
		ACRES	PERCENT			CROPLAND	PASTURE	FOREST
Albany	339,840	36,373	11	597	302,000	26	7	55
Rensselaer	425,600	42,577	10	2	381,500	22	6	53
Greene	417,920	19,401	5	239	397,500	11	7	73
Columbia	411,520	10,935	3	7	399,390	33	13	47
Ulster	731,520	50,600	7	644	675,900	11	1	86
Dutchess	522,240	72,330	14	599	448,000	26	10	53
Orange	530,560	74,563	14	18,397	435,400	20	11	52
Putnam	150,400	149,800	99+	0	0	-	-	-
Rockland	113,920	113,450	99+	70	0	-	-	-
Westchester	278,400	277,485	99+	15	0	-	-	-
Bergen, N.J.	149,100	119,900	80	100	28,500	14	0	81
Hudson, N.J.	28,800	26,200	91	900	1,600	-	-	-

(1) New York Conservation Needs Inventory and New Jersey Conservation Needs Inventory of 1967; see sources listed below.

(2) Includes only private, rural land.

Sources: U.S. Department of Agriculture, 1967; 1970.

developments predominate in the remainder of the county, with zones designated for industrial and commercial development present in each of the five townships forming the county. The Palisades Interstate Parkway traverses the county from north to south, and the New York State Thruway from east to west in the southern portion of the county.

Historical Resources

2.118 The Hudson River Estuary is rich in sites and landmarks of historic interest, legacies of the eventful development of one of the longest settled areas in North America. In addition, eminent examples of the architectural style of each of the eras in the region's history abound. The National Register of Historic Places (U.S. Department of the Interior, 1977) contains an extensive list of properties within the Hudson River estuary. Table 2-17 lists properties within 5 miles of the Bowline Point and Roseton Generating Stations. Two properties in the immediate vicinity of the Bowline Point Generating Station are included in the Register. These are the Henry Garner Mansion located approximately one mile from the power plant site, and the Fraser-Hoyer House, also in West Haverstraw. Directly across Haverstraw Bay is the Van Cortlandt Manor, a National Historic Landmark. The Stony Point Battlefield is another National Historic Landmark, located approximately 3 miles north of the power plant site.

2.119 In addition, New York State currently has an active historic preservation program within the Parks and Recreation Department. The Department has on file several structures and sites that are potentially eligible for inclusion in the National Register. Table 2-17 lists properties in the vicinity of the Bowline Point and Roseton Generating Stations that have been nominated or approved by New York State* but have not to date (1 March 1977) been included in the National Register (36 CFR 800) as of 1 March 1977 and become subject to the provisions of the National Historic Preservation Act.

update this :-

2.120 An inventory of historic resources of the Hudson River Valley (Hudson River Valley Commission, 1969) lists several structures of architectural interest in the Town of Haverstraw and the Villages of Haverstraw and West Haverstraw. These are predominantly houses built in the early and middle 19th Century, several churches from the same period and one instance of a two-story clapboard house dating from around 1770.

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*Information on places nominated but not in the National Register has been obtained through personal communication by Mr. Joel Klein, Historic Preservation Program Analyst, New York State Parks and Recreation Department, 4 March 1977.

TABLE 2-17

HISTORIC SITES IN THE VICINITY OF THE BOWLINE POINT AND ROSETON GENERATING STATIONS

Rockland County

Stony Point, Stony Point Battlefield, north of Stacy Point on US 2 and 202
West Haverstraw, Fraser-Hoyer House, Treason Hill, off US 9W
West Haverstraw, Henry Garner Mansion, 18 Railroad Avenue
Palisades Interstate Park, west bank of the Hudson River
New City, New Hempstead Presbyterian Church and School House*

Westchester County

Croton-on-Hudson, Van Cortlandt Manor US 9N of junction with US 9A

Ulster County

None

Orange County

Newburgh, David Crawford House, 189 Montgomery St.
Newburgh, Dutch Reformed Church, NE corner of Grand and 3rd Sts.
Newburgh, Mill House (Gomez the Jew House) Mill House Rd.
Newburgh, Montgomery-Grand-Liberty Streets Historic District, 19th-20th St.
Newburgh, Washington's Headquarters (Hasbrouck House), Liberty and Washington Sts.

Dutchess County

Beacon, Madame Catharyna Brett Homestead, 50 Van Nydeck Ave.
Beacon, Howland Library, 477 Main St.
Beacon, Tioronda Bridge, South Ave.
Fishkill, Fishkill Village District, along N.Y. 52 from Cary St. to Hopewell St.
Fishkill vicinity, Fishkill Supply Depot Site
Fishkill vicinity, Van Wyck-Wharton House, south of Fishkill on US 9
Verplanck, Verplanck-Van Wyck Barn, town of Wappinger*
Beacon, Eustatis, NW of Beacon of N.Y. 9D*

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*Denotes sites nominated to or approved by New York State for nomination to, but not on, the National Register of Historic Places as of 1 March 1977.

Recreational Resources

2.121 A broad range of recreational resources exists along the Hudson River and within the contiguous counties. The river provides opportunities for noncontact recreation such as boating, fishing, bird-watching and, in addition, swimming in some areas. The river provides a backdrop for camping, hunting, hiking, sightseeing and motoring.

2.122 The study area contains numerous skiing resorts, state parks, such as Catskill Park and the Palisades Interstate Park, and many other smaller recreational facilities. There are many private and semiprivate resorts, country clubs and other recreational facilities in the area.

CHAPTER 3

RELATIONSHIP OF THE PROJECT TO LAND USE PLANNING

3.01 The Bowline Point Generating Station occupies a 245-acre tract in the Town of Haverstraw and Village of West Haverstraw, Rockland County, New York.* Located approximately 30 miles north of New York City, the Town of Haverstraw is one of several established centers of industry and commerce along the Hudson River between the Albany-Troy, Schenectady and New York metropolitan areas.

3.02 Haverstraw was incorporated as a village in 1854 with a mayor-council system of government. The original village gained rapidly in importance following the introduction of steam navigation on the Hudson River in 1807. Traprock quarrying became one of the major activities in the area. Other industries, which at one time thrived or are still active, include the manufacture of cement, brick and other building products, paint, hardware, textiles, and leather and metal novelties.

3.03 The riverfront areas of the Town of Haverstraw and the adjacent Town of Stony Point to the north have been traditional sites of clay quarrying and brick manufacturing. Deposits of coal ash and debris from these activities and other industrial rubble remain in the area. The power plant site, originally part of the Grassy Point Marsh formed by the deltas of the Cedar Pond Brook and Minisceongo Creek, most recently had been used as a municipal landfill and for the unauthorized disposal of discarded automobiles, household applicances and trash (Orange and Rockland, 1971).

3.04 Preparation owrk at the site included the removal of garbage, vegetative clearing, pest control, filling, grading and drainage improvements. Approximately 60 acres of wetlands were affected by the construction of the power plant and associated facilities. All major site work and construction related to the Bowline Point Station and the recreational facility on site is now complete. The power plant is a prominent visual feature in the view from the river and is visible from many residential sections and a considerable length of shoreline.

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*Counties in New York are subdivided into legally incorporated towns, also referred to as townships, and cities. With one exception (the City of Sherrill in the Town of Vernon, Oneida County), towns and cities are independent civil entities. In addition, there are incorporated villages, each lying within one or more towns. New York comprises 930 towns, 62 cities and 533 villages (Rand McNally, 1976).

RELATIONSHIP TO LOCAL LAND USE

3.05 Rockland County in its land use plan designates the site of the Bowline Point Generating Station as a utility zone and the area immediately to the northwest of the site as an industrial zone (County of Rockland, 1973). Adjacent to these are zones of high density (five or more dwelling units per acre) and medium density (two to four dwelling units per acre) residential development and zones of commercial development. Modest homes forming well-established neighborhoods, small retail businesses and public buildings predominate in the vicinity of the power plant.

3.06 There is no indication that the Bowline Point Generating Station has had any tangible effect on land use in the villages of Haverstraw and West Haverstraw or in the greater area of the Town of Haverstraw. Property values generally have not declined since 1973, despite completion and operation of the power plant and the stagnant economic conditions in southeastern New York over the period (Rotella, 1977). The area has experienced no abnormal growth or decline in population nor discernible changes in urbanization patterns, industrialization or business activities (Rotella, 1977).

3.07 Development of the site has entailed the loss of some open space of marginal recreational value. On the other hand, the owners of the plant have contributed substantially towards the establishment of the Bowline Point Municipal Park and related amenities. The facility proved to be a popular local attraction during its first year of operation and it is anticipated that public use of the facility will increase in coming years (Rotella, 1976, 1977).

3.08 The station provides employment for a permanent work force of approximately 100 (U.S. Federal Power Commission, Form No. 1, Annual Report of Orange and Rockland Utilities, Inc., 31 December 1976) that includes trained plant operators, administrative personnel and maintenance staff. Employees commute to the site from a wide area. The plant operates 24 hours a day in three shifts and, during shift changes, automobile traffic to and from the plant increases but causes no appreciable congestion on local roads (Rotella, 1976, 1977).

up to

3.09 Subsequent to the improvements in access to the site made during the construction phase of the project, no need to upgrade local highways or railroads has become evident. Fuel oil is delivered to the site by barge or tanker. The added river traffic is readily accommodated and poses no undue hazard to waterborne commerce or pleasure boating. Occasional deliveries of equipment and materials to the power plant constitute a minor added demand on railroad and highway transportation systems serving the area.

3.10 The land use plan of the County of Rockland shows that part of the waterfront in the Town of Haverstraw remains dedicated to industrial development (County of Rockland, 1973). Improvements at the Bowline Point site have generally upgraded the industrial potential of the area through enhanced drainage and access to the site and the termination of trash disposal. These improvements, together with a strengthening of the municipal tax base, might constitute an attraction to future industrial ventures in the area.

3.11 The station's visibility and visual dominance evidently have not affected local and use to a discernible degree. The extent to which these factors might influence future development or redevelopment in the area is difficult to gauge, particularly if massive natural draft cooling towers are installed. The presence of the power plant is certain to contribute heavily to the industrial, character of its surroundings and may inhibit certain types of residential, commercial or recreational developments.

3.12 Operation of the Bowline Point Generating Station is unlikely to influence future land use planning or development as a result of the plant's consumption of water, discharge of airborne emissions and liquid effluents, generation of solid wastes, and interaction with the aquatic ecosystem of the Hudson River.

RELATIONSHIP TO LAND USE ON THE HUDSON RIVER ESTUARY

3.13 For several years electrical generating facilities have provided a focus for concerns over the effects of urbanization and development on the natural, recreational and cultural resources of the Hudson River estuary. Attention has been directed particularly to projects in the early stages of planning that ultimately could be sited on the Hudson River. Considerable public opinion has favored the adoption of land use planning and controls as means of averting or minimizing potential problems.

3.14 Accomplishments along these lines constitute important elements of a comprehensive land use strategy. Legislative initiatives in New York have led to its being one of the nation's strongest authorities over matters of land use (U.S. Council on Environmental Quality, 1976). Laws provide, among other things, for the protection of wetlands, designation of environmentally fragile and historically significant areas, and participation by the State in management programs authorized by the Coastal Zone Management Act of 1972. In addition, the laws impose several requirements on the State's electrical utility companies, including requirements to disclose long-term generation and transmission plans and to identify sites held for future expansion.

3.15 Notwithstanding the statutory power of the State, much of the authority to formulate policies on growth and to regulate development remains vested in local government. Although land use plans have been developed for all of the counties on the Hudson River estuary, many with the aid of funds made available by the State of New York or through the Comprehensive Planning Assistance Program authorized by Section 701 of the Federal Housing Act of 1954, evidence of coordination at a regional level is fragmented. In the case of counties on the lower estuary--Hudson and Bergen Counties in New Jersey; the boroughs of New York City; and Rockland, Westchester, Putman, Organge, Dutchess and Ulster Counties in New York--the land use plans of individual counties have been integrated by the Tri-State Regional Planning Commission into comprehensive guidelines for regional development. Established initially as the Tri-State Regional Planning Commission by agreement among the governors of New York, New Jersey and Connecticut, the interstate agency now coordinates the goals and plans of 22 counties or boroughs in New York and New Jersey and six planning regions in southwest Connecticut under provisions of legislation in all three states. Through efforts to develop tools for cross-acceptance of regional and subregional land use plants, the Commission has successfully formulated and ensured a degree of consistency in the regional development guide covering the greater New York metropolitan area.

3.16 Growth in counties of the mid-Hudson region (Orange, Putnam, Dutchess, Ulster, Sullivan, Greene and Columbia Counties) has been the subject of extensive study by Mid-Hudson Pattern, Inc., an independent nonprofit organization engaged in community planning, research and development. Established in 1965, its basic function is to provide government and private enterprise with technical, research and planning assistance to promote informed decisions on issues concerning the future development of the mid-Hudson. Generally broader in geographical scope, the Regional Plan Association is a second civic organization which, since its first charter as a committee of the Russell Sage Foundation in 1922, has concentrated its efforts on developing regional approaches to problems facing the greater New York City area. Other instances of coordinated planning to satisfy the varied needs of this populous region have been isolated and aimed primarily at specific targets such as waste water treatment, transportation systems, or upgrading of recreational facilities.

3.17 Recognition of the value of a coordinated planning, comprehensive in scope both with respect to geographical extent and diversity of human need, if reflected in the establishment of the

Hudson River Valley Commission by New York State Executive Law, Section 721. In the early 1960s the Commission was granted authority to review proposed projects within one mile of the Hudson River shore, or within two miles if visible from the river, to determine whether such projects would destroy or substantially impair significant historic or recreational resources or cause major changes in the appearance or use of water.

3.18 While in the early stages of construction, the Bowline Point Generating Station was subject to the Commission's review. The Commission expressed reservations regarding the visibility of the station and the architectural merit of the plant's structures and expressed uncertainty, in view of the paucity of data then available, regarding the plant's impact on the aquatic ecosystem of the Hudson River. Nonetheless, following a public hearing held in the Town of Haverstraw on 3 February 1970 and consideration of the costs and benefits associated with the project, the Commission concluded that the benefits outweighed the costs, and accordintly, that the project would not exert an unreasonably adverse effect on the scenic, natural and recreational resources of the Hudson River Valley.

3.19 The functions of the Hudson River Valley Commission have been transferred to the New York State Department of Environmental Conservation but without allocations for personnel or an operating budget. Several responsibilities mandated in the Commission's original charter, particularly those concerning planning of water and related land resources, are now within the purview of the Coastal Zone Management Program administered by the Division of Planning, New York Department of State. On the basis of procedures and criteria developed in the first year of the program study, the entire Hudson River estuary falls within the initial delineation of the Coastal Zone. The State has applied for (19 March 1976) and received a grant covering the second year of a 4-year planning period under the terms of Section 306 of the Coastal Zone Management Act of 1972. The Coastal Management Office intends to expand and refine the results of the first year program and to perform additional required work.

3.20 Much of the second year grant will be suballocated to local governments to support their coastal zone management planning interests. Where matters of statewide, regional or intermunicipal concerns are noted, the State's Coastal Zone Management Program will identify the specific means for resolving differences, where these exist. Public participation will be significantly increased during the second year. In addition to the New York Department of State, participants in the program will include local governments, regional planning boards, the New York Department of Environmental Conservation and the New York Sea Grant Institute. Primary objectives will include giving clear, accurate information on the nature and scope of the Coastal Zone Management Program to the public, expanding and refining methods to obtain adequate levels of input from various public and private sources, and establishing a workable path from private interests through local and regional agencies to a statewide management program. The Coastal Zone Management Program thus provides an opportunity for State, local governments and the public to work collaboratively in promoting a wise and effective use of coastal zone resources. A management plan is due to be released to the public and submitted to the Federal Coastal Zone Management Office for approval in the fall of 1977. It is expected that the plan will include guidelines and criteria related to the siting of future energy facilities along the Hudson River.

3.21 A second comprehensive program is currently underway to evaluate the water resources of the entire Hudson River Basin. The 2-year Level B study sponsored by the Water Resources Council will draw on the input of several Federal, State and local governmental agencies to assess the adequacy of available resources in meeting anticipated needs and to address potential problems resulting from conflicting water and related land uses. As major consumers and users of water, existing and future power plants along the Hudson River will constitute one of the study's points of scrutiny.

Status of study? completed?

3.22 Through a comprehensive assessment of the needs of communities on the Hudson River estuary and the carrying capacity of its varied resources, these ongoing studies undoubtedly will shed light on the complex issues that surround the siting of power plants. Until regionwide development options and recommendations are formulated, however, an understanding of the of the relationship between power generating facilities and land use on the estuary can be only rudimentary.

3.23 The Bowline Point Generating Station is not unique inasmuch as it conforms to the traditional proactice of locating a power plant in proximity to the load centers it serves, on a site with adequate water resources to supply the plant's cooling requirements and capable of accommodating modest expansion. Alternative trends in siting are emerging. Among these are the concept of clustering facilities in power parks and a growing tendency to locate power facilities in power parks and a growing tendency to locate power plants in remote, sparsely populated areas and transporting energy over increasingly long distances. Such strategies may or may not prove beneficial in terms of land use on the Hudson River estuary. Clearly, the Bowline Point and Roseton Generating Stations neither establish nor reinforce similar departures from the conventional approach to power plant siting.

CHAPTER 4

ENVIRONMENTAL IMPACTS OF THE PROJECT

4.01 The potential environmental impacts associated with the Bowline Point Generating Station and the cumulative impacts resulting from the operation of all of the existing generating facilities on the Hudson River estuary are presented in this section. Impacts on the physical, biological and human resources of the study area are analyzed in terms of the predominantly localized effects attributable to the operation of the Bowline Point and Roseton generating stations and the aggregated effects of present and future developments. Where appropriate, the analysis encompasses impacts that are regional in character and may be experienced beyond the limits of the study area.

4.02 All of the generating stations on the Hudson River presently operate with once-through condenser cooling systems. Requirements to install closed-cycle cooling at the Bowline Point, Roseton and Indian Point (Units 2 and 3) have been imposed by the U.S. Environmental Protection Agency. These requirements, in all instances, are being contested and are the subject of presently on-going adjudicatory hearings before the Agency (Appendix B).

update to current Status re Settlement Agreement.

IMPACTS ON PHYSICAL RESOURCES

4.03 The operation of the Bowline Point Generating Station and other steam electric facilities on the Hudson River estuary represents a potential source of impact on the physical resources of the study area. Concern centers principally on the rejection of waste heat to the river and the release of contaminants in airborne emissions and waterborne effluents. Potential effects on the physical environment include the alteration of the temperature and flow regime of the Hudson River estuary and the deterioration of ambient air and water quality. Delivery of fuel oil to the fossil fueled plant involves a risk of major spills and poses a further threat to the water resource.

Thermal Regime of the Hudson River Estuary

4.04 The characteristics of the thermal discharges from the Bowline Point Generating Station and the Roseton-Danskammer stations, as well as the combined thermal discharges from all of the existing and proposed power plants on the Hudson River estuary, have been studied extensively through mathematical modeling and computer simulations (Appendix E). The principal objective of the analysis is to determine under which conditions applicable water quality standards relating to thermal discharges could be exceeded.

New York State Criteria Governing Thermal Discharges

4.05 New York criteria governing thermal discharges (6NYCRR704) to estuaries or portions of estuaries provide that:

(1) The water temperature at the surface of an estuary shall not be raised to more than 90 F at any point.

(2) At least 50 percent of the cross sectional area and/or volume of the flow of the estuary, including a minimum of one-third of the surface as measured from water's edge to water's edge at any stage of tide, shall not be raised to more than 4 F over the temperature that existed before the addition of heat of artificial origin or a maximum of 83 F, whichever is less.

(3) From July through September, if the water temperature at the surface of an estuary before the addition of heat of artificial origin is more than 83 F, an increase in temperature not to exceed 1.5 F at any point of the estuarine passageway as delineated above, may be permitted.

(4) At least 50 percent of the cross-sectional area and/or volume of the flow of the estuary including a minimum of one-third of the surface as measured from water's edge to water's edge at any stage of tide, shall not be lowered more than 4 F from the temperature that existed immediately prior to such lowering.

4.06 Consideration of the provision that surface temperatures not exceed 90 F necessitates a detailed analysis of the behavior of the thermal plumes in the immediate vicinity of the Bowline Point and Roseton discharge diffusers. Analytical techniques are available to determine the levels of dilution in the near-field zones and the reduction in temperature of the discharge through mixing with the receiving waters before it reaches the surface of the estuary. The results of the analysis are generally quoted in terms of dilution ratios. Given a dilution ratio, the surface temperature in the vicinity of a discharge can be computed if the temperature of the water at the power plant intake, the ambient temperature at the discharge, and the rise in temperature across the condenser are known.

4.07 Near-field analyses cannot take into account such longer range phenomena as the recirculation of cooling water from a plant's discharge to its intake or the cumulative thermal interactions of power plants on a common body of water. A study of these effects requires the application of far-field techniques. One-dimensional techniques generally yield a broad overview and indicate where a more detailed investigation might be warranted. A two-dimensional or near-field-far-field analysis then is needed to study the spatial variation of temperature or any other relevant parameter in sufficient detail.

The Hudson River Estuary

4.08 Hydraulic and thermal analyses of the Hudson River estuary are rendered complex by the reversals in flow due to tidal action. Under conditions of reversing flow, the phenomena of reentrainment (the ambient water diluting a discharge is at an elevated temperature as a result of receiving the discharge or a separate thermal discharge at an earlier tidal phase) recirculation through a power plant and alternating multiplant interactions become important considerations. The locations of the thermal plumes change continuously in large portions of the river and quasi steady-state thermal conditions may be attained only after numerous flow-reversal periods. Field surveys are difficult to conduct under these conditions since an accurate representation of temperature over a substantial portion of the river would require deployment of a large number of boats, personnel, and equipment.

4.09 Further, a determination of whether a particular thermal discharge causes certain regulatory criteria to be exceeded is rendered difficult by the presence and possible influence of other discharges to the river. The New York State Criteria refer both explicity and implicity to conditions that prevail or would prevail in the absence of a thermal load of artificial origin. Without reversing flows, natural temperatures are generally a fair representation of the undisturbed conditions in the river. If the flow reverses periodically, on the other hand, natural temperatures can be determined only by field measurements taken at "reasonable distances" either upstream or downstream of the plant. The situation on the Hudson River is such that the zones of thermal influence about existing power plants overlap, making it impossible to ascertain through measurements alone the degree to which natural conditions are altered by each individual plant.

True?
or just more
difficult

Local Thermal Analysis at the Bowline Point and Roseton Generating Stations

4.10 The local dilution characteristics of the thermal discharge from the Bowline Point station (near-field analysis) have been examined on the basis of numerical simulations and available field data (Appendix E). The analyses show that (surface) dilution ratios for the Bowline Point diffuser vary from approximately 2 to a maximum of 6 (Appendix E). Values in the low end of the range apply when flow in the river is predominantly parallel to the diffuser, that is, under conditions close to flood tide. The higher values apply at or near ebb tide and high slack water. Since the temperature rise across the power plant condenser is nominally 15 F, an excess temperature of 7.5 F at the surface near the diffuser could be experienced under worst case conditions.

4.11 Dilution ratios for the Roseton diffuser are estimated to range from 3 to 6 (Appendix E). Thus, with a temperature rise of 18 F across the condensers of the Roseton station, the maximum excess surface temperature in its vicinity would be 6 F. The near-field analysis also indicates that the thermal plume from the Danskammer Generating Station at plant loads below 60 percent of rated capacity does not penetrate the Roseton discharge area. With the Danskammer plant operating above this power level, the thermal plumes overlap, and predictions of the maximum surface temperatures that result cannot be made by means of near-field simulations.

Analysis of Cumulative Impacts of all Generating Stations

4.12 The overall thermal effect of power plant operations on the entire Hudson River estuary (far-field analysis) has been assessed through the application of a tidal-transient computer simulation model. All the important natural and power plant induced effects that can influence the thermal conditions in the estuary are considered in the model and its associated computer code ESTONE. The model is one of the general one-dimensional "Unified Transport Approach" models being developed specifically to assess the thermal, chemical, radiological, and biological impacts that operating power plants exert on the aquatic ecology of large receiving water bodies. Details of computer model are given in the Draft EIS (Appendix E) and in Appendix E of this report.

Was it ever completed.

4.13 The far-field analysis of the Hudson River estuary focuses on the 6-month portion of the year from 1 April through 30 September. This period is considered the most critical with respect to the life cycle of the striped bass and certain other fishes of the Hudson River. Further, the highest natural temperatures in the estuary prevail within this period and the possibility is greatest that the thermal discharges from the power plants would give rise to temperatures in excess of regulatory criteria. Data collected in 1973 and 1974 underlie the analysis. Information relating to the physical conditions of the river (freshwater flow, tidal conditions, atmospheric conditions and so on) is used both to validate the model and to assess the thermal effects due to power plants. Operational information on the power plants is used to predict temperature

what about more recent data?

distributions in the estuary on the basis of physical conditions prevailing in 1964 (a drought year) and 1974 (a year of more typical flow).

4.14 For modeling purposes, the Hudson River estuary from the Federal dam at Troy to the Battery (152 miles) is divided in 76 discrete elements, each 2 miles in length. Numerical solutions of the equations incorporated in ESTONE are derived in time steps of 0.0625 hours. The computed results are stored at every 16-time step interval, providing a temperal resolution of 1-hour over the 6-month simulation period. Daily-average conditions are derived from hourly values. Computational details of the model are given in the Draft EIS, Appendix E, Section 3.4.2, and in Appendix E of this Final EIS.

4.15 Results of the Far-Field Analysis for 1974 Conditions. Several cases are considered in the analysis to evaluate the thermal effects associated with each power plant and their cumulative effects on the estuary (See Draft EIS, Appendix E, Section 3.4.5.2). These cases are:

- Case 1 - "Clean River." This case establishes the conditions that would have prevailed in 1974 if no artificial heat load had been imposed on the river by any power plants. The results provide a baseline or point of reference to compare the results of the analysis to regulatory criteria that relate to natural conditions.

- Case 2 - 1974 Conditions. Data collected in 1974 are used to simulate the effects of power plant operating during that year.

- Case 3 - Proposed Maximum Thermal Load Conditions. Operation of all existing power plants at full rated capacity and with once-through cooling, and the proposed Greene County nuclear power plant with closed-cycle cooling is considered.

- Case 4 - Full Once-Through Thermal Load Conditions. The simulation relates to the full power operation of existing power plants, and the proposed Greene County plant, all with once-through cooling.

- Case 5 - Clean River with Only Roseton and Danskammer Power Plants. This simulation yields an estimate of the contribution of the Roseton and Danskammer stations to the thermal loading of the river.

not logical

If these are factored in, then cornwall flow augmentation should had been factored in as well and along with that of the Chelsea pumping Station.

- Case 6 - Clean River with Only the Bowline Point Power Plant. This simulation yields an estimate of the contribution of the Bowline Point Generating Station to the thermal loading on the river.

What Happened to the Lovett Station?

- Case 7 - Proposed Maximum Thermal Load (as in Case 3) Except Bowline Point Station Point with Closed-Cycle Cooling. A comparison with the results of Case 3 provides an estimate of the reduction in the thermal loading of the estuary that would result from the installation of closed-cycle cooling at the Bowline Point station only.

- Case 8 - Proposed Maximum Thermal Load (as in Case 3) Except Indian Point Power Plant with Closed-Cycle Cooling. A comparison with the results of Case 3 provides an estimate of the reduction in the thermal loading of the estuary that would result from the installation of closed-cycle cooling at the Indian Point station only.

4.16 The results of the simulations show that water temperatures in excess of the regulatory criterion of 83 F could occur under physical conditions similar to those prevailing in 1974 (see Table 3.4.13 in Appendix E of the Draft EIS). Predicted excesses occur in the 2-mile segment of the river in the vicinity of Indian Point and are all less than 1 F in magnitude. Maximum temperatures of 83.80, 83.87 and 83.42 F are predicted in Cases 3, 4 and 7, respectively. The last of these indicate that the 83 F criterion would be exceeded under proposed maximum thermal load conditions, regardless of whether or not a closed-cycle cooling system is installed at the Bowline Point station. The maximum temperature that would occur in the critical 2-mile segment without an artificial heat load (clean river conditions) is predicted to be 80.49 F. The contribution from the Bowline Point and the Roseton-Danskammer stations would raise this maximum by 0.4 and 0.3 F, respectively.

4.17 More specifically, the results of the simulations, based on the physical conditions prevailing in the estuary in 1974 and daily-averaged, cross section-averaged and (2-mile) segment-averaged temperatures, are:

(1) Under proposed maximum thermal loading of the river (Case 3, all existing power plants with open-cycle cooling, Greene County plant with closed-cycle cooling), the regulatory criterion limiting temperature increases to 4 F above natural conditions would not be exceeded.

(2) Under full once-through cooling load (Case 4) the same 4 F regulatory criterion would not be exceeded.

(3) Under Case 3 conditions, the regulatory criterion limiting the maximum temperature over 50 percent of the cross-sectional area of the river to 83 F would be exceeded.

(4) Under Case 4 conditions, the same 83 F regulatory criterion would be exceeded.

(5) Conditions prevailing under Case 3 would not be alleviated by the installation of closed-cycle at the Bowline Point station alone to the point where the same 83 F regulatory criterion would be met.

(6) Conditions prevailing under Case 3 would be alleviated by the installation of closed-cycle cooling at Indian Point stations alone to the point where the same 83 F regulatory criterion would be met.

both units?

(7) Operation of the Greene County nuclear station with once-through cooling instead of the proposed closed-cycle cooling would not appreciably raise the temperature in the critical 2-mile segment of the river between Bowline Point and Indian River.

4.18 In summary, the far-field analysis for 1974 conditions indicates that the thermal conditions in the Hudson River estuary, with the existing configuration of power plants and the configuration expected in the near future and under typical physical conditions of the river at the warmest times of the year are very close to the limitations stipulated by New York State thermal criteria.

4.19 Near-Field-Far-Field Analysis of 1974 Conditions. On the basis of findings of the far-field thermal analysis, a 10-mile section of the Hudson River along which the Indian Point, Lovett and Bowline Point stations are located, has been selected for detailed analysis (Draft EIS, Appendix E, Section 3.5). A systematic zone-matching methodology is applied to study the two-dimensional (with results integrated over depth) temperature distributions in the vicinity of the Bowline Point, Indian Point and Lovett stations. The analysis relates to Case 3; namely, operation of all existing power plants at full rated capacity and with once-through cooling and the proposed Greene County nuclear power plant with closed-cycle cooling.

not in the
11 mile zone?

4.20 The results of the near-field-far-field analysis in the vicinity of the Bowline Point station indicate that certain New York State regulatory criteria would be exceeded occasionally. Specific findings based on the river conditions of 4 August 1974 (Draft EIS, Appendix E, Section 6.1.3) are:

> Critical thermal conditions in the Hudson River in the vicinity of the Bowline Point station will occur generally during the afternoon and evening hours, between 13:00 and 22:00 hours, on various days in July and August. Operation of the station gives rise to temperatures in the river in excess of regulatory standards by virtue of (a) the occurrence of surface temperatures in excess of 91 F (90 F limit), (b) the occurrence of temperatures of 84 F (83 F limit) over one-third of the surface as measured from water's edge, and (c) the occurrence of temperatures of 84 F (83 F limit) over 50 percent of the cross-sectional area or volume of the flow of the estuary.

4.21 Results applicable to the thermal distribution in the Hudson River in the vicinity of the Indian Point station, again based on natural conditions prevailing on 4 August 1974, are:

> Critical thermal conditions will occur generally during the afternoon and evening hours between 1300 and 2200 hours on various days in July and August. Operation of the Indian Point station with once-through cooling will give rise to temperatures in excess of regulatory standards by virtue of (a) the occurrence of surface temperatures of 84 F (83 F limit) at the surface of the river from water's edge to water's edge (limit of one-third of the surface) and (b) the occurrence of temperatures of 84 F (83 F limit) over 100 percent of the cross-sectional area or volume of flow (50 percent limit).

4.22 Results of the Far-Field Analysis for 1964 Conditions. In response to comments received on the Draft EIS, a far-field computer analysis has been carried out for the low-flow drought conditions of 1964. Because the proposed Greene County power plant has been cancelled since the publication of the Draft EIS, this power plant was removed from the model runs for the 1964 conditions. Results of the model runs are given in Appendix E.

why was it included in the 1974 run?

Three cases have been considered:

- Case 1 - "Clean River." This case establishes the conditions that would have prevailed in 1964 if no artificial heat load had been imposed on the river by the operation of any power plants. The results provide a baseline or point of reference to compare the results of the analysis to regulatory criteria.
- Case 2 - Rated Load. Operation of all existing power plants at 90 percent of rated capacity with once-through cooling.

- Case 3 - Projected Load. Operation of the Bowline Point, Indian Point, Lovett, Danskammer, and Roseton stations at power levels projected to be typical averages in the future (projected power levels supplied by the Utilities). The power level for Indian Point, Albany Steam Station and 59th Street Power Plant were set at 90 percent of rated capacity. All power plants were simulated with once-through cooling.

4.23 The computer simulation results for the longitudinal distributions of water temperature conditions along the estuary for the projected load and rated load cases were compared with the "clean river" case to determine the far-field thermal impact of multi-power-plant operation on the Hudson River during the six-month period 1 April - 30 September 1964. Since the computer simulations were begun on 1 April 1964, the month of April was not included in the considerations of the far-field thermal analysis because quasi-steady state thermal conditions were not reached during one month. Therefore, the computer simulation results for the longitudinal distributions of water temperature conditions along the estuary were considered for the period 15 June - 30 September 1964.

4.24 Simulation results were calculated for:

- daily-averaged, cross-section-averaged water temperature
- daily-maximum, cross-section-averaged water temperature
- daily-averaged surface water temperature
- daily-maximum surface water temperature

The results were presented graphically as

- longitudinal distributions of water temperature conditions along the estuary on midmonth and endmonth days during 15 June - 30 September 1964.
- daily variations of the local water temperature conditions at Indian Point (model element 55) and Bowline Point (model element 58) during the six-month period.

4.25 Examination of the computer simulation of longitudinal temperature distribution along the Hudson River indicates that the greatest effect of power plant operations under 1964 river flow conditions occurs in the portion of the river between Bowline Point and Indian Point, which is effected by the discharge from those plants as well as the Lovett station. Simulation results also indicate that New York State standards governing thermal discharges would be violated in this reach of the river by operation of the power plants with once-through cooling under 1964 river flow conditions.

4.26 With respect to the temperature standard specifying a maximum water temperature increase of 4F when the natural river temperature is less than 83F, violations occurred only under the Rated Load case near Indian Point for three to eight day periods during June and September. Violations were slight, however, with 4.4F being the greatest temperature increase occurring. Violations of this magnitude would be within the error limits of the model. No violations occurred under the Projected Load case.

4.27 Violations of the criterion restricting the maximum water temperature increase to 83F occurred for estimated periods of 9 to 40 days during June, July, and August near Indian Point and Bowline Point. Violations occurred under both the Projected Load and Rated Load cases.

4.28 Violations of the criterion limiting maximum water temperature increases to 1.5F when natural river temperatures are greater than 83F occurred near Indian Point and Bowline Point under both the Projected and Rated Load cases. Violations for estimated periods of 10 to 30 days occurred near Indian Point during June, July, and August. A violation occurred during an estimated 10 day period in late July and early August near Bowline Point.

Summary Conclusions of Thermal Analysis

4.29 The following general conclusions may be drawn from the overall thermohydraulic analysis of the Hudson River Estuary:

(1) During years of normal river flow, water temperatures in the river will occasionally and under certain natural conditions exceed applicable New York State standards as a result of the operation of all existing plants at full power and with open-cycle cooling.

(2) During drought years, water temperatures in the river will exceed New York State standards as a result of the operation of all existing plants with open-cycle cooling and at average power level less than full rated power.

(3) Maximum temperatures will occur in the vicinity of the Bowline Point, Lovett and Indian Point stations.

(4) Use of cooling towers at Indian Point would have the greatest effect on reducing water temperatures in the region of the river between Bowline Point and Indian Point.

(5) Excesses in temperature over regulatory criteria are not inordinate under normal flow conditions, but increase with decreasing flow of fresh water in the river as would occur during drought years.

Flow Regime of the Hudson River Estuary

4.30 Although the direct consumption of water at the Bowline Point Generating Station and at other generating stations on the Hudson River estuary is small, the heat load imposed on the river by the operating power plants promotes evaporation at a rate greater than would naturally prevail and effectively results in a consumptive use of the water resource. The rate at which additional losses of water are incurred is determined by a large number of factors, including the characteristics of the thermal plume and prevailing meteorological conditions. The U.S. Environmental Protection Agency estimates that, as a general rule, the rate of evaporation of water associated with a once-through cooling system is 1/2 to 2/3 the rate of evaporation from a mechanical draft evaporative cooling system in comparable service (39 FR 36193, 8 October 1974). Assuming further that 75 percent of the heat rejection from a mechanical draft system is effected through the mechanisms of evaporation, the evaporative losses associated with the Bowline Point station amount to an estimated 7 to 12 cubic feet per second (computed at a latent heat of evaporation of water of 970.3 BTU per pound at 1.0 atmospheres and 77°F).

4.31 Upper estimates of the water losses resulting from the operation of all the existing power plants on the Hudson River estuary with open cycle cooling are:

GENERATING STATION	HEAT REJECTION RATE (Billion Btus per hour)	WATER LOSSES	
		Cubic Feet Per Second	Million Gallons Per Day
Fifty-ninth Street	0.34	0.8	0.52
Bowline	5.17	12	7.8
Lovett	2.38	5.5	3.6
Indian Point	13.3	30	19
Roseton	5.92	14	9
Danskammer	2.97	6.8	4.4
Albany	9.82	4.2	2.7
TOTAL	31.9	73	47

4.32 The total estimated losses of the order of 70 cubic feet per second are small in comparison to the average annual flow of 13,000 cubic feet per second gaged at Green Island (National Commission on Water Quality, 1975). It may be well to note that the flow at Green Island represents the major portion but not the entire flow of fresh water into the lower Hudson River. As indicated previously, the oscillating tidal flow in the estuary can exceed the flow of freshwater by a factor of 10 to 100, making these losses of even lesser significance when the rejection of waste heat gives rise to the evaporation of brackish or saline water.

4.33 In terms of the flow regime of the lower Hudson River, the evaporative losses of water caused by the rejection of waste heat from existing power plants are considered to be negligible. The same conclusion is expected to hold true if and when closed cycle cooling systems are installed at the Bowline Point station and other eligible power plants in accordance with the requirements of 40 CFR 423. Evaporative consumption at those plants is then expected to be 1.5 to 2 times the values given above. Clearly, however, there would be a limit to the additional waste heat from future steam electric stations that could be accommodated without appreciably affecting the movement of the salfront or other hydrologic characteristics of the river or substantially depleting the freshwater resource.

Water Quality

4.34 The operation of the Bowline Point Generating Station and other generating stations on the Hudson River estuary is a potential cause of degradation in the quality of the receiving waters as a result of the discharge of heat, residual quantities of chlorine in the cooling water, and contaminants in the various liquid waste effluents from the power plants. Liquid wastes are discharged in controlled amounts both during normal operations and during periods when the power plants are shut down for maintenance. Limitations are imposed on the properties of the discharges by the National Pollutant Discharge Elimination System permits authorizing the discharge of liquid wastes from each of the stations. Further, these limitations reflect "the degree of effluent reduction attainable by the application of best available technology economically achievable" (40 CFR 423) at the Bowline Point and Roseton generating stations and other eligible facilities, as required by the Water Pollution Control Act Amendments of 1972 (PL 92-500).

Bowline Generating Station

4.35 Liquid effluents from the Bowline Point Generating Station meet all the limitations imposed by the current National Pollutant Discharge Elimination System Permit (Appendix B) issued to Orange and Rockland by the U.S. Environmental Protection Agency, authorizing the discharge of liquid wastes from the station. Ongoing surveys at Bowline Point show that water quality is not being affected measurably and that applicable water quality standards established by the State of New York are not being violated as a result of the operation of the plant. A summary of the principal characteristics of waterborne effluents from the Bowline Point Station is given in Table 4-1. A more detailed discussion of waterborne waste streams from Bowline is given in Appendix D.

4.36 Discharge of Chemical Compounds and Sanitary Wastes. Releases of chemical compounds associated with the operation of Bowline generating station are primarily those stemming from boiler blowdown. Estimates indicate that residual quantities of chemical compounds present in the blowdown will occur in receiving waters in maximum concentrations ranging from 0.01 and 0.25 milligrams per liter (Orange and Rockland, 1974a). While some of the chemical compounds that might be discharged in the blowdown from the Bowline Point boilers (hydrazine, disodium phosphate, sodium hydroxide, sodium sulfite and cyclohexylamine) and certain derivatives of these compounds are known to be toxic to aquatic life (U.S. Atomic Energy Commission, 1973), there are no reports of toxic effects associated with such contaminants at concentrations likely to be encountered in the Hudson River as a result of the discharges from the Bowline Point Station.

Sanitary wastes from Bowline are discharged to the Haverstraw municipal sewage system.

TABLE 4-1

CHARACTERISTICS OF WATERBORNE EFFLUENTS FROM THE BOWLINE POINT GENERATING STATION

WASTE STREAM	DISCHARGE			PRINCIPAL CHARACTERISTICS OF THE DISCHARGE		
	FREQUENCY	RATE	DISPOSAL	PROPERTIES		EFFLUENT LIMITATIONS IMPOSED BY NPDES PERMIT
Condenser cooling water	Continuous	768,000 gallons per minute	Hudson River	Heat addition rate:	5.6 billion Btu per hour	5.8 billion Btu per hour
				Maximum temperature:	93.5F	102F
				Temperature rise:	13.5F	23F
				Free available chlorine:	0.1 milligrams per liter, maximum	0.2 milligrams per liter maximum, 48.5 pounds per day
				Chlorination schedule:	Occasional, as required; suspended when water temperature is below 50F	Chlorination suspended when water temperature is below 50F
				pH:	Ambient river	6.0 to 9.0 or 0.2 pH units valuation from intake
				Velocity at travelling screens:		0.77 feet per second maximum daily average
				Oil and greese:	None added	None discharged
				Soils:	None added	No deposition or deleterios effects
				Ambient standards in receiving waters:	Applicable New York State standards	Applicable New York State standards
Boiler blowdown	Once daily	121,000 gallons	Hudson River	Trace quantities of:	Hydrazine, sodium sulfite, disodium phosphate, sodium hydroxide, cyclohexylamine	All limitations applicable to condenser cooling water
				pH:	8.0 to 9.5	
Prefilter backwash, water treatment system	Once weekly	10,500 gallons per wash	Hudson River	Suspended solids:	Filtered from municipal water supply	All limitations applicable to condenser cooling water
Service water strainer backwash	Twice weekly	9,000 gallons per wash	Hudson River	Suspended solids:	Accumulated river debris	All limitations applicable to condenser cooling water
Air preheater washdown	Once quarterly	1,800 gallons per wash	Hudson River	Solids:	Suspended and dissolved products of oil combustion	All limitations applicable to condenser cooling water
				pH:	Acidity increases from 3.5 to 7 during each washdown	
Boiler seal trough	Continuous	15 gallons per minute	Hudson River	Solids:	Ash	All limitations applicable to condenser cooling water
Demineralizers regeneration, water treatment system	Once every 3 days	17,000 gallons per regeneration	Municipal sewage treatment plant	Solids:	Dissolved sodium sulphate mineral salts suspended microsized particles	None Applicable
				pH:	Neutral	
Boiler cleaning wastes	Once yearly	-	Off site	-	-	None applicable
Plant laboratory wastes	Intermittent	-	Municipal sewage treatment plant	-	-	None applicable
Sanitary wastes	Intermittent	-	Municipal sewage treatment plant	-	-	None applicable
Stormwater runoff from oil storage are	Intermittent	-	Minisceongo Creek to Hudson River	Oil and grease:		15 milligrams per liter average, 20 milligrams per liter maximum
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Cooling tower blowdown	Continuous	6,600 gallons per minute	Hudson River	Heat addition rate:	0.06 Btu per hour	0.090 billiong Btu per hour October through May, 0.015 billion Btu per hour June through September
				Maximum blowdown temperature:	99F	99F
				Toxic wastes and deleterious substances	No discharge	No discharge

4.37 Surface Runoff. Stormwater runoff from roofs, yards, roadways and parking lots is discharged to Minisceongo Creek and the Hudson River through the station drainage system. Runoff from the fuel storage facility is collected in a 2,000 gallon sump. Collected stormwater is monitored by means of an oil detector and, in most circumstances, is processed by an oil-water separator even when the concentration of oil is below the limit stipulated in the National Pollutant Discharge Elimination System permit (a maximum concentration of 20 milligrams per liter of oil and grease and a daily average concentration of 15 milligrams per liter). Following exceptionally heavy precipitation, the processing may be suspended if monitoring indicates that the discharge would meet the regulatory limitations. Waste oil recovered from the separator is collected periodically for disposal by a commercial waste contractor. Degradation of Hudson River water quality from these sources will be small compared to the magnitude of other waste streams entering the river.

4.38 Chlorination. Chlorination is not needed at Bowline on a regular schedule. When chlorine is added, predictions (Orange and Rockland, 1974) indicate that residual quantities of free available chlorine at concentrations of 0.1 milligrams per liter diluted further in the receiving waters and reduced in time through chemical reactions and atmospheric losses, should not be toxic to aquatic organisms.

4.39 Ambient Water Quality in Receiving Waters. Surveys of water quality have been in progress in the vicinity of Bowline and Lovett generating stations since 1971 (Orange and Rockland, 1974a; 1975; 1976). Measurements of approximately 30 standard water quality parameters have been made once a month since mid-June 1973. A summary of data on selected parameters observed during 1974 and 1975 together with pertinent details of the sampling program are given in Appendix D.

4.40 Several years of water quality monitoring of the Hudson River in the vicinity of Bowline Point confirm the results of predictive analyses and preliminary conclusions of earlier, less complete surveys, namely that the waterborne discharges from the Bowline Point station cause no measurable degradation in the quality of the receiving waters of the Hudson River. Apart from temperature, there are no observations that would indicate a change in any of the monitored parameters attributable directly or indirectly to the operation of the Bowline Point station.

4.41 Dissolved oxygen at the plant discharge is generally equal to or greater than that measured at the other sampling stations, implying that the circulating water system does not directly lower or adversely affect the level of dissolved oxygen in the river. The observed monthly values follow the well known seasonal trend of decreasing dissolved oxygen levels with increasing ambient river temperatures, reaching a low point of the order of 6 milligrams per liter in midsummer and a high 13 milligrams per liter in winter. Sample values below 5.0 milligrams per liter (the applicable New York State standard) have been observed. Extreme low readings of 4.8 milligrams per liter in the Bowline Point Channel and 4.5 milligrams per liter in Bowline Pond are recorded for 1974 and 1975, respectively, and are probably a result of eutrophic conditions in the river.

4.42 Observed pH values show no marked differences in the measurements made at each of the stations. The pH is relatively constant throughout the year with an average value of approximately 7.5. The extreme range of pH in the individual observations made in the 2-year period is 6.8 to 8.0.

4.43 The ongoing survey in the vicinity of Bowline Point confirms the fact that the waters of the lower Hudson River are rich in nutrients. Measured values of total nitrogen (nitrates plus Kjeldahl nitrogen) and total phosphorus are of the order of 1 milligram per liter and 0.1 milligram per liter, respectively, both indicative of a eutrophic system (U.S. Council on Environmental Quality, 1976). Occasional low values of dissolved oxygen occur naturally in such systems. While the eutrophic conditions in the river cannot be related to the operation of the Bowline Point Generating Station, these are the most likely cause of the infrequent observations of dissolved oxygen values below 5.0 milligrams per liter.

4.44 Yearly average measurements of fecal coliforms at the four sampling stations ranged approximately between 600 and 1,500 cells per 100 milliliters in 1974 and between 450 and 1,400 counts per 100 milliliters in 1975. Measurements on individual samples exhibit much larger variations with observations ranging as high as 5,000 to 8,000 cells per 100 milliliters. The average levels are generally lower than a geometric mean of 2,000 cells per 100 milliliters recommended for public water supplies (U.S. Environmental Protection Agency, 1973), but higher than 200 cells per 100 milliliters considered desirable in bathing waters (U.S. Council on Environmental Quality, 1976; U.S. Environmental Protection Agency, 1976).

4.45 Among the heavy metals monitored in the vicinity of Bowline Point and Lovett Generating Stations, chromium and lead were not found in 1975 at levels above 0.10 and 0.08 milligrams per liter, respectively, the limits of detectability of the particular methods employed in the survey (Orange and Rockland, 1976). Observed concentrations of zinc ranged from values less than 0.10 milligram per liter to 0.29 milligram per liter and concentrations of iron ranged from values less than 0.03 to 3.53 milligrams per liter, with a yearly average of approximately 0.65 milligram per liter.

4.46 Impact on Ambient Water Quality. Waterborne discharges from the Bowline Point Generating Station to the Hudson River are made into waters classified by the State of New York as SB or suitable for bathing and other usages except shellfishing for market purposes (Parts 700-703, Title 6, Official Compilation of Codes, Rules and Regulations, New York State). Applicable standards for Class SB waters are the following:

Items	Specification
Floating solids; settleable solids; oil; sludge deposits; solids	None attributable to sewage, industrial wastes or other wastes
Garbage, cinders, ashes, oils, sludge or other refuse	None in any waters of the marine district as defined by State Conservation law
Sewage or waste effluents	None which are not effectively disinfected
Dissolved oxygen	Not less than 5.0 parts per million
Toxic wastes, deleterious substances, colored or other wastes or heated liquids	None alone or in combination with other substances or wastes in sufficient amounts or at such temperatures as to be injurious to edible fish or shellfish or the culture or propagation thereof, or which in any manner shall adversely affect the flavor, color, odor or sanitary condition thereof; and otherwise none in sufficient amount to make the waters unsafe or unsuitable for bathing or impair the waters for any other best usage as determined for the specific waters which are assigned to this class

4.47 The liquid effluents from the station currently lead to no violation of applicable water quality standards. Individual water samples taken in the vicinity of the station indicate that the dissolved oxygen level occasionally and locally drops below the regulatory limit of 5.0 parts per million. This phenomenon may be attributed to the eutrophic conditions of the Hudson River.

4.48 It is anticipated that the liquid effluents from a closed-cycle cooling system installed at the Bowline Point Station would reflect the application of the best available technology economically achievable (40 CFR 423.13) and, similarly, would not lead to violations of water quality standards in receiving waters.

Roseton Generating Station

4.49 Data on the use of chemical compounds at the Roseton generating station are available only for 1974, a year of partial operation of only one unit (Appendix D). All chemical discharges will meet the requirements of National Pollution Discharge Elimination System permit authorizing the discharge of liquid wastes from the Roseton Generating Station. Operational data are not yet available to assess the effect of chemical discharges on the estuary in the vicinity of Roseton, but preoperational monitoring data have found no effects attributable to discharges from the nearby Danskammer plant. No effects are likely from the Roseton discharge.

True?

update

4.50 **Chlorination.** Chlorination has not been used on a regular schedule at Roseton since the early weeks of operation. When added, dosage is the maximum quantity that can be added without exceeding the limit of 0.5 milligrams per liter free chlorine residual required by New York State water quality standards.

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4.51 **Ambient River Water Quality.** Available data does not include the period of regular operation of the Roseton power units. Several years of preoperational monitoring data in the vicinity has found no changes in water quality attributable to the operation of the nearby Danskammer power plant. Waterborne discharges from the Roseton facility are, likewise, not expected to alter ambient river conditions as they presently exist.

Cumulative Impacts

4.52 The liquid effluents from the Roseton generating station (Central Hudson, 1975) and other steam electric facilities on the Hudson River estuary contain residuals of chlorine, oil and grease, combustion products, and a variety of chemical contaminants. In addition, liquid effluents from the Indian Point Generating Station contain traces of radioactive substances (U.S. Environmental Protection Agency, 1974). The quantities of contaminants released to the river are small and are required to conform to applicable effluent limitation standards established by the U.S. Environmental Protection Agency (40 CFR 423) and design objectives of the U.S. Nuclear Regulatory Commission (10 CFR 50, Appendix I).

4.53 Both the tidal and freshwater flow of the Hudson River are generally several orders of magnitude greater than the flow of liquid discharges from individual plants, providing the potential of diluting waste material to extremely low concentrations. The behavior of contaminants in such circumstances is not well understood, and there are no techniques available to predict the transport and fate of the contaminants and their possible derivatives. While several mechanisms, such as sedimentation, bioaccumulation and chemical interactions could, in principle, lead to substantive cumulative effects, there are at present no indications of potential problems resulting from the operation of power plants on the Hudson River.

4.54 Problems relating to water quality in the lower Hudson River stem principally from the release of nutrients and organic matter from municipal sewage treatment systems, with industrial releases contributing to the organic load (National Commission on Water Quality, 1976). The attendant conditions of low levels of dissolved oxygen and high counts of coliform bacteria are expected to improve markedly by 1985 when the goal of eliminating discharges, expressed in the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500), is realized. It is anticipated that remaining difficulties with respect to water quality will then be associated with the relatively high content of coliform bacteria and heavy metals in urban runoff as well as small contributions of nutrients, pesticides and other contaminants in the storm runoff from nonurban areas (National Commission on Water Quality, 1976). While the relative contribution of power plants to water quality degradation may rise from its present low level, it is expected to remain small or negligible and confined to the release of trace contaminants.

4.55 Water quality surveys to date indicate that no measurable reductions in the dissolved oxygen content of the Hudson River waters occur as a result of thermal discharges from power plants. More detailed field measurements, particularly under less eutrophic conditions in the receiving waters, might reveal a demonstrable reduction in dissolved oxygen within the thermal plumes associated with the discharges. However, hazardously low (to aquatic life) levels of dissolved oxygen are currently absent outside of the Albany and New York City portions of the estuary, and it may be anticipated that the continued operation of existing facilities with once-through cooling would not lead to a significant cumulative lowering of dissolved oxygen in the river waters. From the standpoint of dissolved oxygen, additional heat rejection loads from future power plants might be tolerable, provided interactions among thermal plumes can be avoided. The installation of closed-cycle cooling at all eligible existing plants and future power plants effectively eliminates the possibility of a significant lowering of the dissolved oxygen content of the Hudson River waters.

will be tolerable

error

Air Quality

4.56 The releases of airborne contaminants from the Bowline Point and Roseton Generating Stations and other fossil fueled stations within the study area is subject to state regulations governing the composition and use of fuels in stationary combustion installations. New York State regulations (6 NYCRR, Parts 225, 227) limit the permissible content of sulfur in fuel oil burned at the Fifty-Ninth Street, Bowline Point and Lovett stations to 0.37 percent by weight and to 2.0 percent by weight in fuel burned at the Roseton, Danskammer (changed to 1.0 percent on 1 August 1976) and Albany stations. The ash content of all fuel oil is required to be sufficiently low to limit emissions of particulate matter to a maximum rate of 0.10 pounds per million BTU heat input, averaged over 2 hours. Emission rates of nitrogen oxides are limited to 0.30 pound per million BTU heat input.

4.57 Field measurements of air quality in the vicinity of the Bowline Point Generating Station have shown that New York Ambient Air Quality Standards (6 NYCRR, Parts 256, 257) for particulates, sulfur dioxide and nitrogen dioxide have not been exceeded as a result of operating the power plant.

4.58 Monitoring data taken in 1975 and early 1976 in the vicinity of the Roseton Generating Station indicate that the New York State hourly* and 24-hour standards** for sulfur dioxide were being exceeded occasionally. All other applicable state standards

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*An hourly standard for sulfur dioxide was in effect at the time of writing. The hourly standard has been rescinded (6 NYCRR, Part 257, effective 18 March 1977) in New York State.

**The 24-hour New York State standard for sulfur dioxide requires that the 24-hour concentration not exceed 0.14 part per million and also that 99 percent of 24-hour values during 12 consecutive months not exceed 0.10 part per million. Observations near the Roseton facility show that only the first provision of the standard is being exceeded occasionally.

for sulfur dioxide, particulates and nitrogen dioxide were being met. Observations from several stations within the Roseton monitoring network indicated that the Federal secondary standard for suspended particulates (24-hour concentration) was being exceeded occasionally. Central Hudson reports that, since 1 August 1976 when the sulfur content of the fuel oil burned at the Danskammer power plant was reduced from 2.0 to 1.0 percent, compliance with the New York 24-hour standard for sulfur dioxide has been achieved.

4.59 The possibility has been examined that airborne emissions from the Roseton and Danskammer stations might act cumulatively with emissions from the Bowline Point and Lovett stations to produce undesirably high concentrations of sulfur oxides (Appendix E). The results of a numerical simulation show no evidence that annual average concentrations of sulfur dioxide at ground level approach Federal standards (Appendix E of the DEIS, Section 4.3.3). The Albany and 59th Street stations are considered to be too far removed from the other stations in the study area to contribute appreciably to cumulative concentrations of sulfur oxides at ground level.

4.60 The operation of evaporative cooling towers at fossil fueled stations within the study area introduces the potential for interactions among the plumes from stacks and cooling towers, with the consequent formation of acidic mists. Knowledge of the physical and chemical phenomena in merged plumes is incomplete and a precise assessment of the attendant risk of affecting air quality or producing adverse effects at ground level cannot be made. Information available to date indicates that impacts resulting from plume interaction at the Bowline Point and Roseton stations, or other stations on the Hudson River Estuary, would not be appreciable (Appendix E, Section 4.3.5).

Air Quality at Bowline Point

4.61 Numerical simulations (Orange and Rockland, 1971; 1972; 1973), carried out before the Bowline Point Generating Station was put into operation, indicated that certain New York State ambient air quality standards could be exceeded as a result of operating the power plant. The analyses showed that both hourly* and 24-hour average limitations on sulfur dioxide concentrations would be exceeded on the ridge line (High Tor ridge) and peak areas to the southwest of the station during periods of stable atmospheric conditions and moderate winds.

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*The hourly standard for sulfur dioxide concentration is no longer in effect in New York State.

4.62 Orange and Rockland instituted a program to monitor pertinent meteorological and air quality parameters at several monitoring stations in the vicinity of the site both before and after the initial operation of the Bowline Point units. Three stations were located on the High Tor ridge where the concentrations of sulfur dioxide were expected to be the highest under certain meteorological conditions.

4.63 In addition, Orange and Rockland sponsored a measurement program to observe the behavior of the plumes from the Bowline Point station stacks using fluorescent particle tracers injected into the stack (Orange and Rockland, 1976). Five sets of observations were made on three separate days between 19 January and 31 July 1976 when meteorological conditions were predicted to be most conducive to direct contact of High Tor by the plume. On each of these occasions, the prevailing combination of wind speed and atmospheric stability were such that the plume was located above the ridge and no direct contact occurred. Further, the time averaged dilution, or dispersion of the plume was sufficiently great to prevent the concentration of sulfur dioxide on the ridge from exceeding ambient standards. An examination of meteorological data gathered at the Bowline Point station between August 1972 and April 1976 shows no instance when conditions of wind and stability would lead to the fumigation of High Tor ridge, and the possibility of the critical combination of meteorological factors occurring is taken to be remote on the basis of both the available ovservation and meteorological records.

4.64 Annual reports summarizing the results of meteorological and air quality measurements from June 1974 to May 1975 (Orange and Rockland, 1975) and and June 1975 to May 1976 (Orange and Rockland, 1976) have been prepared and filed with the New York State Department of Environmental Conservation. No instances of state air quality standards being exceeded have been reported to date (Burns, 1976).

4.65 The possibility of burning less expensive fuel oil with a sulfur content greater than 0.37 percent by weight has been investigated (Orange and Rockland, 1976). Numerical simulations practical fuel switching program involving fuel oils with sulfur contents of 0.37 and 2.2 percent. Orange and Rockland has applied to indicate that ambient air quality standards can be maintained under a the New York State Department of Environmental Conservation for authorization to implement the fuel switching program.

4.66 Air Quality Monitoring. Air quality monitoring in the vicinity of the Bowline Point station region began in 1970. Observations were made at various times between 1 May 1970 and 31 August 1972 to establish baseline conditions before Unit 1 was put into commercial service (Orange and Rockland, 1973). Measurements of the ambient concentrations of sulfur oxide and particulates were made at four locations in the Haverstraw area, the primary location being the office building of the Rockland County Health Department in Haverstraw. Measurements of nitrogen oxides concentrations were made at one site only, the New York State Rehabilitation Hospital. Early analysis of measurements showed that data from the various monitoring stations could be combined to yield a reasonable representation of air quality in the general vicinity of the power plant (Orange and Rockland, 1973a).

4.67 Summary results of preoperational air quality monitoring are given in Tables 4-2 and 4-3. The principal findings, based on data given in these tables as well as cumulative probability distribution developed from measurements of nitrogen oxide concentrations over a 6-month period, are as follows:

(1) Prevailing concentrations of sulfur dioxide were substantially below New York State air quality standards. Observed hourly average concentrations reached 25 percent of standards, while daily and annual averages reached 50 percent of the respective standards.

(2) Observed concentrations of particulates ranged in value from levels corresponding to 70 percent of standards to values in excess of these standards.

(3) Average 24-hour concentrations of nitrogen oxides would exceed the ambient standards of 0.05 parts per million roughly 64 percent of the time during a period of 12 consecutive months. Further, correlations of air quality and meteorological observations indicated that all three airborne contaminants, observed routinely in high concentrations, were not of local origin. The data suggested that airborne contaminants migrated from the southeast across Haverstraw Bay and, from the southwest, from the Ramapo, Mawah and Hackensack River Valleys.

4.68 A monitoring program designed to measure sulfur dioxide concentrations attributable to the operation of the Bowline Point station was instituted in March 1972 in response to the stipulations of the New York Department of Environmental Conservation. A network of six real-time (continuous) stations was established in the vicinity of the station at points identified in Figure 4-1. Provisions have been made to monitor concentrations of particulate matter and nitrogen dioxide at three of the stations. Pertinent characteristics of the network are given in Table 4-4.

TABLE 4-2

SUMMARY OF PREOPERATIONAL OBSERVATIONS OF SULFUR DIOXIDE CONCENTRATIONS AT BOWLINE POINT

PERIOD	OBSERVED CONCENTRATIONS IN PARTS PER MILLION		NEW YORK STANDARDS IN PARTS PER MILLION	
	99 PERCENT FREQUENCY	MAXIMUM OBSERVED	99 PERCENT FREQUENCY	MAXIMUM OBSERVED
1-Hour Average Concentration*				
1 May 70-31 Aug 72	0.058	0.128	0.25	0.50
1 Sep 70-31 Aug 71	0.069	0.128	0.25	0.50
1 Sep 70-31 Aug 72	0.047	0.096	0.25	0.50
Summers	0.053	0.100	0.25	0.50
Winters	0.068	0.128	0.25	0.50
24-Hour Average Concentration				
1 May 70-31 Aug 72	0.051	0.070	0.10	0.14
1 Sep 70-31 Aug 71	0.057	0.070	0.10	0.14
1 Sep 71-31 Aug 72	0.037	0.04	0.10	0.14
Summers	0.035	0.052	0.10	0.14
Winters	0.057	0.070	0.10	0.14
ANNUAL AVERAGE		**OBSERVED**		**AVERAGE**
1 May 70-31 Aug 72		0.0158		0.030
1 Sep 70-31 Aug 71		0.0172		0.030
1 Sep 71-31 Aug 72		0.0141		0.030

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*Hourly standard for sulfur dioxide concentration is no longer in effect in New York State.

Source: Orange and Rockland, March 1973a.

TABLE 4-3

SUMMARY OF PREOPERATIONAL OBSERVATIONS OF TOTAL SUSPENDED PARTICULATE CONCENTRATIONS AT BOWLINE POINT

STATION	CONCENTRATION OF PARTICULATES IN MICROGRAMS PER CUBIC METER: HI-VOLUME EQUIVALENT	CONCENTRATION OF PARTICULATES IN MICROGRAMS PER CUBIC METER: HI-VOLUME SAMPLE	NEW YORK STANDARDS IN MICROGRAMS PER CUBIC METER
50 PERCENT FREQUENCY			
Health Department Bldg.	58	73	65
Bowline Point Tower	65.5	-	65
Health Department Bldg. and Bowline Point Tower	62	73	65
84 PERCENT FREQUENCY			
Health Department Bldg.	85	96	100
Bowline Point Tower	92	-	100
Health Department Bldg. and Bowline Point Tower	87	96	100
100 PERCENT FREQUENCY			
Health Department Bldg.	199.7	124	250
Bowline Point Tower	218.5	178	250
Health Department Bldg. and Bowline Point Tower	218.5	178	250

Source: Orange and Rockland, March 1973a.

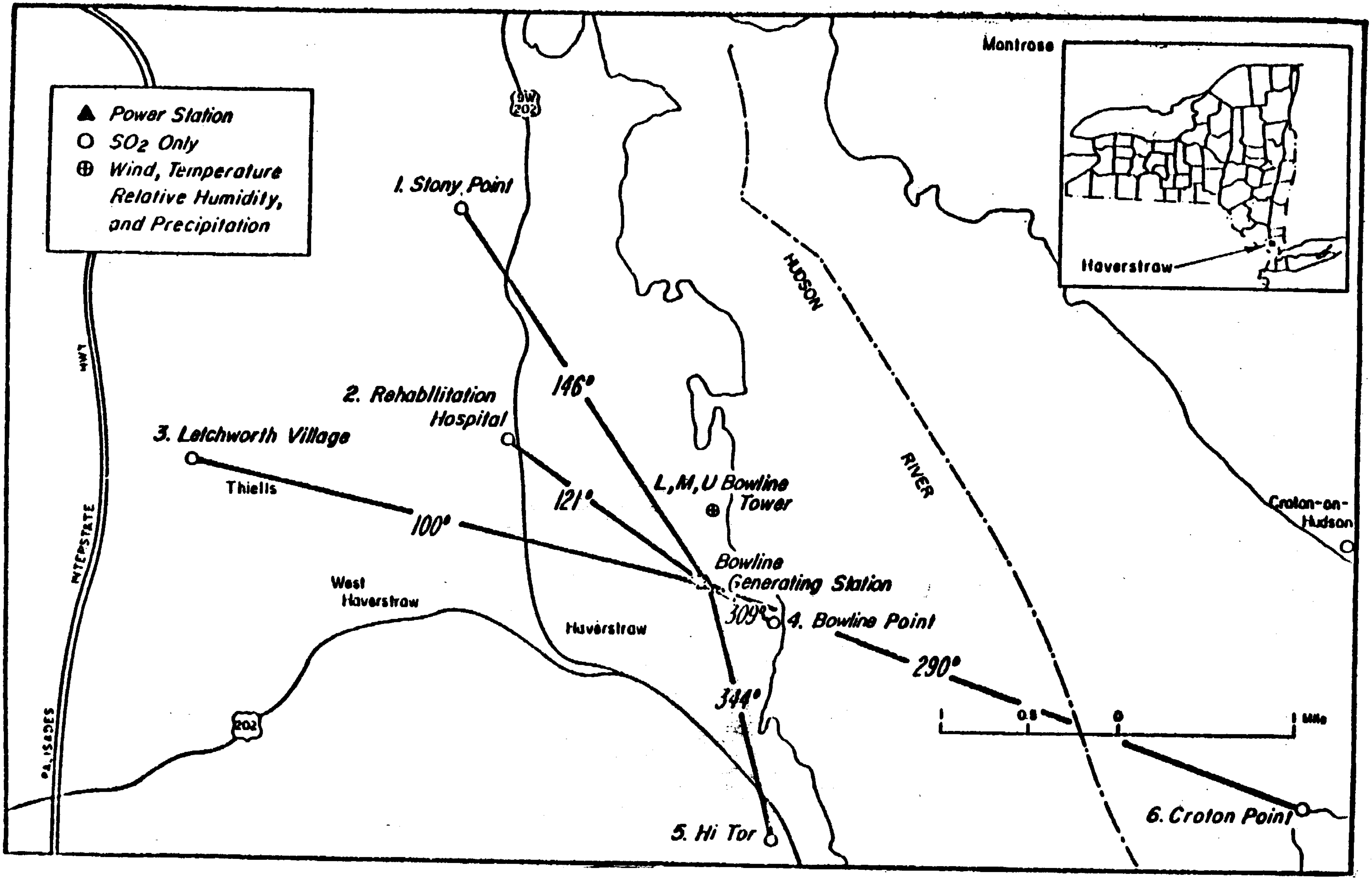

FIGURE 4-1
HAVERSTRAW, NEW YORK AIR MONITORING NETWORK (Directions indicated are those of winds that would blow from the plant towards the monitoring stations).

TABLE 4-4

CHARACTERISTICS OF THE AIR QUALITY MONITORING NETWORK AT BOWLINE POINT

STATION NUMBER	STATION	ELEVATION,(1) FEET	DOWNWIND SECTOR,(2) DEGREES	DISTANCE FROM POWER PLANT, MILES
1	Stony Point	220	116-176	2.6
2	Rehabilitation Hospital	180	91-151	1.4
3	Letchworth Village	450	70-130	3.1
4	Bowline Point	8	279-339	0.5
5	Hi Tor	564	314-014	1.5
6	Croton Point	62	260-320	3.8

(1) Feet above mean sea level. The top of the stacks at the Bowline Point Generating Station is 287 feet above ground level and 297 feet above mean sea level.

(2) The downwind sector is the sector ± 30 degrees from the wind direction that places the station downwind of the power plant; angles are measured clockwise from a reference of due north at 0° or 360°.

Source: Orange and Rockland, July 1976.

4.69 Quarterly and yearly reports documenting the results of field measurements have been prepared since the inception of the monitoring program. The latest available annual report (Orange and Rockland, 1976) contains data pertaining to sulfur dioxide measurements from June 1975 to May 1976. A summary of the measured average daily concentrations is given in Table 4-5. The data show no instance of the ambient standard of 0.1 part per million being exceeded during the period under consideration.

4.70 Summaries of results derived from measurements of nitrogen dioxide concentrations (from June to November 1974 and March to May 1975) and particulate concentrations (September 1974 to November 1974 and December 1974 to May 1975) are given in Tables 4-6 and 4-7. The observed concentrations of nitrogen dioxide measured hourly and averaged monthly are generally well below 0.05 part per million, with monthly averages approaching this value only occasionally. Accordingly, it appears unlikley that the standard of 0.05 part per million, applicable to observations taken over 12 consecutive months will be exceeded. Maximum hourly measurements of nitrogen dioxide concentrations are substantially higher and occasionally reach values of the order of 0.6 part per million. Data on concentrations of particulates show no instance of state standards being exceeded during the monitoring period.

4.71 Measured concentrations of nitrogen dioxide taken after the Bowline Point station became operational, therefore, differ substantively from the preoperational concentrations discussed previously. The later information shows that lower concentrations prevail, suggesting either a reduction in background levels or deficiencies in one or both sets of measurements. No data are available from alternative sources to indicate the more likely explanation for the apparent discrepancy.

Air Quality at the Roseton Generating Station

4.72 An air quality monitoring network has been established in the vicinity of the Roseton and Danskammer generating stations. The individual stations making up the network are identified in Figure 4-2 and pertinent information on the station is given in Table 4-8.

4.73 Summaries of data collected over the 12-month period from March 1975 through February 1976 are given in Tables 4-9, 4-10, and 4-11 (data on sulfur dioxide concentrations) and Tables 4-12 and 4-13 (data on total suspended particulate and nitrogen oxide concentrations, respectively). Measurements of sulfur dioxide concentrations indicate that 99 percent of hourly average values are below the New

TABLE 4-5

SUMMARY OF SULFUR DIOXIDE OBSERVATIONS AT BOWLINE POINT, JUNE 1975 THROUGH MAY 1976

MONTH	NUMBER OF DAYS WITH AVERAGE DAILY CONCENTRATIONS IN EXCESS OF 0.10 PARTS PER MILLION/NUMBER OF DAYS OF OBSERVATIONS					
	STONY POINT	REHABILITATION HOSPITAL	LETCHWORTH VILLAGE	BOWLINE POINT	HI TOR	CROTON POINT
<u>1975</u>						
June	0/18	0/29	0/30	0/30	0/21	0/30
July	0/30	0/22	0/30	0/29	0/27	0/30
August	0/31	0/23	0/31	0/31	0/31	0/31
September	0/30	0/30	0/30	0/30	0/30	0/30
October	0/31	0/30	0/31	0/30	0/31	0/28
November	0/29	0/30	0/30	0/19	0/30	0/28
December	0/30	0/28	0/28	0/31	0/31	0/28
<u>1976</u>						
January	0/31	0/25	0/31	0/31	0/30	0/30
February	0/29	0/23	0/29	0/27	0/28	0/29
March	0/31	0/31	0/26	0/31	0/23	0/29
April	0/28	0/30	0/29	0/30	0/30	0/30
May	0/31	0/14	0/31	0/28	0/31	0/31

Source: Orange and Rockland, July 1976.

TABLE 4-6

SUMMARY OF NITROGEN DIOXIDE LEVELS AT BOWLINE POINT, JUNE 1974 THROUGH MAY 1975.

STATION	MONTH AND YEAR	DATA CAPTURE, PERCENT	NITROGEN DIOXIDE CONCENTRATIONS, PARTS PER MILLION	
			MAXIMUM HOURLY	MONTHLY AVERAGE
STONY POINT	Jun 74	79	0.033	0.005
	Jul 74	50	0.030	NA
	Sep 74	95	0.180	0.049
	Oct 74	97	0.155	0.030
	Nov 74	61	0.194	NA
	Mar 75	100	0.094	0.021
	Apr 75	98	0.125	0.038
	May 75	100	0.116	0.038
LETCHWORTH VILLAGE	Jun 74	53	0.146	NA
	Jul 74	100	0.095	0.022
	Aug 74	100	0.084	0.027
	Sep 74	100	0.116	0.027
	Oct 74	100	0.155	0.031
	Nov 74	100	0.133	0.030
	Mar 75	99	0.107	0.026
	Apr 75	99	0.150	0.023
	May 75	99	0.165	0.046
HI TOR	Jun 74	27	0.088	NA
	Sep 74	84	0.103	0.022
	Oct 74	90	0.166	0.037
	Nov 74	700	0.164	0.030
	Mar 75	99	0.095	0.025
	Apr 75	98	0.458	0.044
	May 75	98	0.568	0.044

Sources: Orange and Rockland, November 1974; February 1975; July 1975.

TABLE 4-7

SUMMARY OF TOTAL SUSPENDED PARTICULATE OBSERVATIONS AT BOWLINE POINT, SEPTEMBER 1974 THROUGH MAY 1975

PERIOD	TOTAL SUSPENDED PARTICULATE CONCENTRATIONS IN MICROGRAMS PER CUBIC METER, EXCEPT AS NOTED		
	STONY POINT	LETCHWORTH VILLAGE	WEST HAVERSTRAW SUBSTATION
<u>SEPTEMBER 1974-NOVEMBER 1974</u>			
Data capture, percent	84.6	69.2	85.7
Computed geometric mean	31.3	35.9	36.2
Computed standard deviation	2.0	1.8	1.7
Number of excesses of:(1)			
24-hour N.Y. State standard	0	0	0
24-hour Federal primary standard	0	0	0
24-hour Federal secondary standard	1	0	0
<u>DECEMBER 1974-MAY 1975</u>			
Data capture, percent	93.4	76.4	91.8
Computed geometric mean	32.6	46.5	47.0
Computed standard deviation	1.8	1.7	1.6
Number of excesses of:(1)			
24-hour N.Y. State standard	0	0	0
24-hour Federal primary standard	0	0	0
24-hour Federal secondary standard	0	1	0

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(1) The Federal standards are values not to be exceeded more than once a year. New York State standards, until 18 March 1977, were maximum values.

Source: Orange and Rockland, November 1974; February 1975; July 1975.

1974

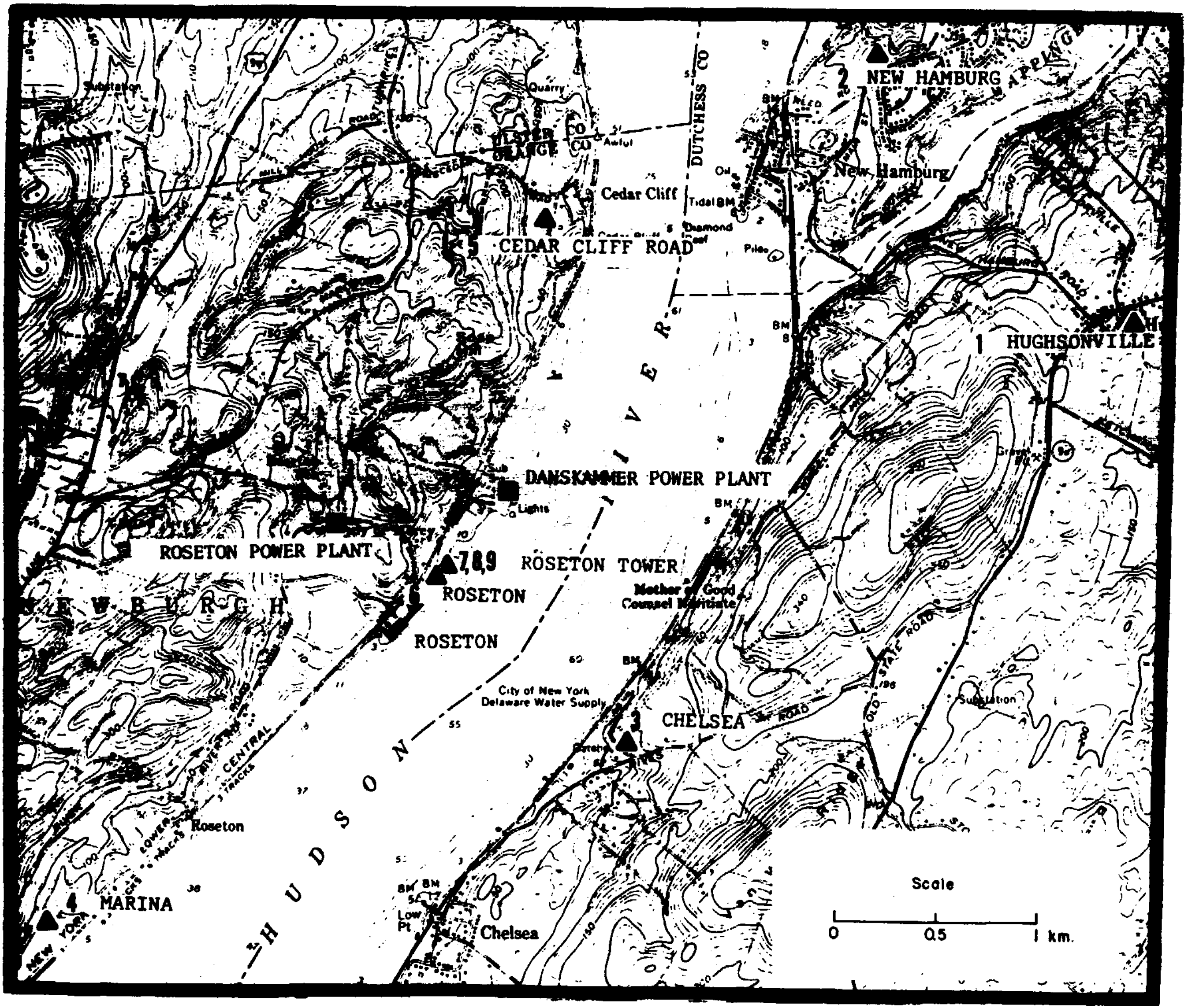

FIGURE 4-2
MONITORING NETWORK FOR THE DANSKAMMER AND ROSETON POWER PLANTS

TABLE 4-8

CHARACTERISTICS OF THE AIR QUALITY MONITORING NETWORK AT THE ROSETON STATION

STATION NUMBER	STATION	ELEVATION FEET[1]	DOWNWIND SECTOR, DEGREES[2]		DISTANCE FROM POWER PLANTS, MILES
			FROM DANSKAMMER	FROM ROSETON	
1	Hughsonville	132	225-285	226-286	2.1-2.5
2	New Hamburg	122	190-250	199-259	1.7-2.2
3	Chelsea	83	304-004	277-337	0.9-1.1
4	Marina	8	017-077	006-066	1.9-1.6
5	Cedar Cliff Road	115	157-217	183-243	0.9-1.1
A	Wheeler Hill Road	325	255-315	245-305	1.0-1.6
6	Roseton	6	009-069	266-326	0.4-0.3

(1) Feet above mean sea level.

(2) The downwind direction is the direction of a wind that places the station downwind of the power plant. The downwind sector is subtended by an arc ± 30 degrees centered on the downwind direction. Angles are measured clockwise from North at 0°.

Source: Central Hudson, June 1976.

TABLE 4-9

SUMMARY OF HOURLY SULFUR DIOXIDE OBSERVATIONS AT ROSETON STATION, MARCH 1975 THROUGH FEBRUARY 1976

STATION	OBSERVED HOURLY CONCENTRATIONS OF SULFUR DIOXIDE ABOVE 0.25 PARTS PER MILLION					
				NET GENERATION, MW		
	DATE	TIME	WIND DIRECTION,(1) DEGREES	DANSKAMMER	ROSETON	SULFUR DIOXIDE HOURLY CONCENTRATION, PARTS PER MILLION
1. Hughsonville	5 Jul 75	0900	173	317	399	0.436
	5 Sep 75	1000	175	310	561	0.314
2. New Hamburg	9 Aug 75	1200	177	376	574	0.296
	3 Oct 75	2100	199	383	572	0.283
	8 Oct 75	1200	122	176	852	0.352
	28 Feb 76	0900	229	307	568	0.263
3. Chelsea	8 Mar 75	1600	305	203	1,006	0.267
	26 Mar 75	1600	307	181	1,030	0.291
	26 Mar 75	1800	311	175	1,032	0.291
	4 Apr 75	1000	305	188	1,010	0.281
	4 Apr 75	1100	306	186	1,011	0.266
	4 Apr 75	1300	302	201	1,012	0.306
	4 Apr 75	1400	307	192	1,013	0.265
	4 Apr 75	1600	299	193	1,010	0.333
	4 Apr 75	1700	297	196	1,010	0.358
	30 Jul 75	0900	150	250	930	0.375
4. Marina	31 Dec 75	2200	31	235	284	0.344
	31 Dec 75	2300	29	233	286	0.294
	1 Jan 76	0000	33	233	284	0.319

TABLE 4-9
(Continued)

OBSERVED HOURLY CONCENTRATIONS OF SULFUR DIOXIDE ABOVE 0.25 PARTS PER MILLION

	DATE	TIME	WIND DIRECTION,(1) DEGREES	NET GENERATION, MW		SULFUR DIOXIDE HOURLY CONCENTRATION PARTS PER MILLION
				DANSKAMMER	ROSETON	
5. Cedar Cliff Road	16 Mar 75	1100	129	137	926	0.281
	19 Apr 75	1200	214	151	1,017	0.450
	12 Jun 75	1000	184	343	530	0.285
	23 Jun 75	0200	205	218	546	0.257
	23 Jun 75	0300	209	193	448	0.425
	23 Jun 75	0400	209	187	495	0.375
	23 Jun 75	0500	211	197	550	0.581
	11 Sep 75	2100	176	312	573	0.338
	11 Sep 75	2200	178	284	548	0.304
	12 Sep 75	0100	177	224	298	0.309
	12 Sep 75	0200	174	209	296	0.371
	12 Sep 75	0300	176	207	297	0.443
	12 Sep 75	0400	176	209	297	0.412
	12 Sep 75	0500	177	209	318	0.304
	12 Sep 75	0600	181	223	391	0.253
	4 Oct 75	0400	196	124	455	0.271
	14 Oct 75	1400	195	186	955	0.496
	21 Nov 75	1100	181	338	264	0.306
	21 Nov 75	1200	179	325	266	0.379
	21 Nov 75	1300	184	324	268	0.275
	26 Nov 75	1500	016	361	200	0.261
A. Wheeler Hill Road		NO VALUES EXCEED 0.25 PARTS PER MILLION				

TABLE 4-9
(Concluded)

STATION	OBSERVED HOURLY CONCENTRATIONS OF SULFUR DIOXIDE ABOVE 0.25 PARTS PER MILLION					
	DATE	TIME	WIND DIRECTION,(1) DEGREES	NET GENERATION, MW		SULFUDIOXIDE HOURLY CONCENTRATION PARTS PER MILLION
				DANSKAMMER	ROSETON	
6. Roseton	5 Apr 75	0900	301	184	1,015	0.265
	5 Apr 75	1000	320	205	1,017	0.284
	5 Apr 75	1200	330	189	1,017	0.252
	5 Apr 75	1400	320	156	1,024	0.282
	5 Apr 75	1500	333	156	1,020	0.292
	21 Apr 75	1200	317	156	1,022	0.316
	26 Apr 75	1600	312	114	806	0.278
	30 Jul 75	0900	150	250	930	0.347

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(1) Wind direction measured at the upper level of the Roseton meteorological tower.

Source: Central Hudson, June 1976.

TABLE 4-10

SUMMARY OF 24-HOUR SULFUR DIOXIDE OBSERVATIONS AT ROSETON, MARCH 1975 THROUGH FEBRUARY 1976

	OBSERVED 24-HOUR CONCENTRATIONS OF SULFUR DIOXIDE EXCEEDING 0.10 PARTS/MILLION					
				AVERAGE GENERATION, MW		
STATION	DATE	STARTING HOUR	WIND DIRECTION,(1) DEGREES	DANSKAMMER	ROSETON	OBSERVED SULFUR DIOXIDE CONCENTRATIONS, PARTS/MILLION
1. Hughsonville		NO VALUES EXCEED 0.10 PARTS PER MILLION				
2. New Hamburg		NO VALUES EXCEED 0.10 PARTS PER MILLION				
3. Chelsea	8 Mar 75	0200	308	193	976	0.128
	26 Mar 75	1100	307	197	780	0.122
	3 Apr 75	1900	298	194	982	0.177
4. Marina		NO VALUES EXCEED 0.10 PARTS PER MILLION				
5. Cedar Cliff Road	22 Jun 75	1000	208	212	675	0.173
	23 Jun 75	0300	208	306	602	0.134
	11 Sep 75	2000	177	278	485	0.159
A. Wheeler Hill Road		NO VALUES EXCEED 0.10 PARTS PER MILLION				
6. Roseton	5 Apr 75	0600	322	167	957	0.166
	26 Apr 75	1300	313	120	952	0.103

---

(1) Wind direction is measured at the upper level of Roseton meteorological tower and is averaged over the period beginning 3 hours before and ending 3 hours after the hour of highest sulfur dioxide concentration within the 24-hour averaging period.

(2) Value is the 24-hour running average sulfur dioxide concentration.

Source: Central Hudson, June, 1976.

TABLE 4-11

SUMMARY OF MONTHLY SULFUR DIOXIDE CONCENTRATIONS AT ROSETON, MARCH 1975 THROUGH FEBRUARY 1976

STATION	AVERAGE MONTHLY CONCENTRATION OF SULFUR DIOXIDE, PARTS PER MILLION												
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	12-MONTH AVERAGE
1. Hughsonville	.014	.016	.013	.011	.010	.010	.009	.007	.015	(1)	-	-	.012
2. New Hamburg	.011	.009	.011	.006	.008	.013	.010	.018	.031	.025	.034	.026	.017
3. Chelsea	.031	.038	.013	(1)	.009	.008	.009	.016	.020	.022	.025	.017	.019
4. Marina	.016	.014	.013	.012	.011	.014	.010	.019	.021	.027	.039	.022	.018
5. Cedar Cliff Road	.015	.018	.026	.027	.020	.015	.017	.018	.027	.018	.025	.019	.020
A. Wheeler Hill Road	-	-	-	-	-	-	-	-	-	(1)	.015	(1)	.015
6. Roseton	.019	.033	.011	.008	.009	.010	.007	.010	.018	.019	.022	.017	.015
Average of Stations	.018	.021	.014	.013	.011	.012	.010	.015	.022	.022	.027	.020	.017

(1) Insufficient data to compute a valid average (≥ 480 hours of data per month, 2 months per season and all seasons for an annual computation are required

Source: Central Hudson, June 1976.

TABLE 4-12

SUMMARY OF 24-HOUR TOTAL SUSPENDED PARTICULATE OBSERVATIONS AT ROSETON
MARCH 1975 THROUGH FEBRUARY 1976

STATION	OBSERVED 24-HOUR CONCENTRATIONS OF TOTAL SUSPENDED PARTICULATES EXCEEDING 150 MICROGRAMS PER CUBIC METER					
	DATE	PREVAILING WIND		AVERAGE GENERATION, MW		OBSERVED CONCENTRATIONS, MICROGRAMS PER CUBIC METER
		DIRECTION, DEGREES	SPEED, MPH	DANSKAMMER	ROSETON	
1. Hughsonville	1 Mar 75	308	6	196	844	160.0
	6 Mar 75	274	7	197	996	151.0
	17 Mar 75	14	9	166	912	184.0
	14 Apr 75	322	6	174	529	161.0
	21 May 75	279	4	159	927	189.0
	15 Aug 75	9	7	322	431	182.0
2. New Hamburg	6 Mar 75	274	7	197	996	151.0
	19 Jan 76	24	12	360	279	170.0
4. Marina	12 Apr 75	341	8	126	995	176.0
	20 May 75	198	9	161	884	163.0
	23 May 75	238	7	170	967	173.0
	29 May 75	182	5	163	748	182.0
5. Cedar Cliff Road	15 Apr 75	326	7	162	916	177.0

Source: Central Hudson, June 1976.

TABLE 4-13

COMPARISON OF TOTAL SUSPENDED PARTICULATE OBSERVATIONS AT ROSETON TO APPLICABLE NEW YORK STATE STANDARDS, MARCH 1975 THROUGH FEBRUARY 1976

STATION	PERCENT OF DAILY CONCENTRATIONS[1] OF TOTAL SUSPENDED PARTICULATES BELOW 50 PERCENT STANDARD[2]				PERCENT OF DAILY CONCENTRATIONS[1] OF TOTAL SUSPENDED PARTICULATES BELOW 84 PERCENT STANDARD[3]			
	SPRING	SUMMER	FALL	WINTER	SPRING	SUMMER	FALL	WINTER
1. Hughsonville	47.1	42.3	40.1	—	77.1	73.1	70.6	—
2. New Hamburg	61.6	63.6	65.1	64.1	89.5	88.8	86.9	85.4
3. Chelsea	76.0	76.6	78.8	79.3	96.0	94.6	94.0	98.8
4. Marina	67.1	75.6	79.5	81.2	91.1	92.4	93.5	98.8
5. Cedar Cliff Road	79.9	83.1	84.7	92.8	97.4	97.8	97.8	100.0
A. Wheeler Hill Road	—	—	—	86.1	—	—	—	100.0

[1] Cumulative to end of each quarter.

[2] New York State standards in effect before 18 March 1977 required that 50 percent of daily average concentrations of total suspended particulates be below 55 micrograms per cubic meter at stations 1, 2, 3 and 4 (Level II standard) and 65 micrograms per cubic meter at stations 4 and 5 (Level III). The requirement is no longer in effect.

[3] New York State standards in effect before 18 March 1977 required that 84 percent of daily average values be below 85 micrograms per cubic meter at stations 1, 2, 3 and 4 and 100 micrograms per cubic meter at stations 4 and 5. The requirement is no longer in effect.

Source: Central Hudson, June 1976.

York State standard of 0.25 part per million[*] (Central Hudson Gas and Electric, June 1976). Instances of measured values in excess of 0.25 parts per million are recorded in Table 4-10. Among these, one value of 0.581 parts per million, measured at Cedar Cliff Road on 23 June 1975 is in excess of the regulatory standard of 0.5 parts per million. More than 99 percent of the measured 24 hour concentrations are below the standard for 0.10 parts per million (Central Hudson Gas and Electric, 1976). As indicated in Table 4-11, a total of eight running averages over 24 hours has exceeded 0.10 parts per million, and among these four are in excess of the standard of 0.14 parts per million. The highest 24-hour average concentration recorded over the period is 0.177 parts per million. The monthly average concentrations given in Table 4-12 show that the annual standard of 0.03 parts per million is not exceeded.

4.74 Observed values of total suspended particulate concentrations and applicable state standards are compared in Table 4-13. As indicated, concentrations at one of the stations (Hughsonville) fail to meet standards relating to the distribution of daily average concentrations, both at the 50 and 84 percent levels.[**] However, the geometric mean of 24-hour concentrations measured at all the stations over 12 consecutive months is below the regulatory standard (Central Hudson Gas and Electric, 1976) and no single value above the standard of 250 micrograms per cubic meter has been observed. Recorded 24-hour averages in excess of 150 micrograms per cubic meter, the Federal secondary standard, are listed in Table 4-13; the highest recorded value is 189 micrograms per cubic meter. Operation of the Roseton and Danskammer generating stations is thought to have contributed to particulate concentrations during 2 of the 13 days with highest daily levels over the 12-month period ending in February 1976 (Central Hudson Gas and Electric, 1976).

4.75 Values of the measured concentrations of nitrogen oxides given in Table 4-14 show that the annual average concentration is below 0.05 parts per million at all reporting stations. The standard of 0.05 parts per million of nitrogen dioxide, therefore, is not exceeded. The extreme 24-hour concentrations recorded at certain stations are substantially higher than the annual average, with values ranging to 0.184 parts per million.

4.76 Available information on air quality monitoring in the vicinity of the Roseton station over the period March 1976 to August

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[*] The hourly standard for sulfur dioxide concentrations is no longer in effect in New York State.

[**] These requirements are no longer in effect.

TABLE 4-14

SUMMARY OF NITROGEN OXIDES OBSERVATIONS AT ROSETON, MARCH 1975 THROUGH FEBRUARY 1976

	AVERAGE MONTHLY CONCENTRATIONS OF NITROGEN OXIDES, PARTS PER MILLION												
STATION	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	12-MONTH AVERAGE
2. New Hamburg	.018	.013	.019	.007	.007	.010	.016	.023	.044	.044	.046	.041	.024
3. Chelsea	.014	.014	.017	(1)	(1)	.019	.019	(1)	.043	.044	.041	.030	.024
4. Marina	.022	.022	.037	.015	.016	(1)	(1)	.025	.034	.040	.040	.031	.028
5. Cedar Cliff Road	.012	.009	.043	.031	.027	.032	(1)	(1)	.037	.046	.049	(1)	.031
Highest 24-hr concentration	.079	.143	.118	.103	.090	.079	.066	.102	.194	.194	.169	.138	-
Station number recording highest 24-hr concentration	2	4	5	5	5	5	5	4	5	5	2	2	-
Prevailing wind direction on highest day, degrees	236	226	194(2)	204	140	73	202	191	202	202	022	202	-

(1) Insufficient data to compute a valid average (480 or more hours per month are required).

(2) A concentration of .118 parts per million was recorded twice at the same location in May 1975. On the second occasion the wind was variable.

Source: Central Hudson, June 1976.

1976 (Central Hudson Gas and Electric, 1976) shows that observations continue to be occasionally above applicable standards. Two instances of 24-hour sulfur dioxide concentrations in excess of 0.14 parts per million are recorded (on 27 April 1976 and 13 July 1976) both at the Wheeler Hill Road Station. However, Central Hudson reports that since 1 August 1976 when the sulfur content of fuel oil burned at the Danskammer power plant has been reduced from 2.0 to 1.0 percent by weight, compliance with the New York 24-hour standard for sulfur dioxide has been achieved. Measurements of total suspended particulate concentrations indicate that the state standards are being met. The Federal secondary standard has been exceeded on five separate occasions during the reporting period.

IMPACTS ON BIOLOGICAL RESOURCES

4.77 Operation of electric generating stations on the Hudson River estuary represents a potential source of impacts on the natural upland, wetland, and aquatic ecosystems of the region. Of greatest concern are the effects of the rejection of waste heat to the river and the destruction of small aquatic organisms that are drawn through the power plant condenser system in the cooling water (entrainment) or are killed on the screens used to strain the cooling water flow (impingement).

4.78 The ecology of the Hudson River estuary has been studied extensively over the past 20 years. Major studies have been sponsored by several utility companies, beginning in 1958 with research sponsored by Consolidated Edison to evaluate the impacts of radioisotopes releases by Indian Point Unit No. 1 on man and other biota.

4.79 As a result of the controversy involving the Cornwall Project in the mid-1960s, Consolidated Edison sponsored the Hudson River Fisheries Investigation from 1965-1968 through the Hudson River Policy and Technical Committee, New York Department of Environmental Conservation. Other consultants were starting ecological studies when construction on Indian Point No. 2 was begun in 1968. Raytheon Corporation carried out a series of studies from 1968 through 1971. New York University has ~~been~~ carry~~ing~~ed out studies on entrainment effects at the Indian Point Units 1 and 2 condensers as well as relating the effects of the cooling systems to population of aquatic organisms in the river. Lawler, Matusky, and Skelly Engineers has developed hydraulic thermal models as well as models related to the entrainment of striped bass eggs and larvae.

No longer participating

greater role than these, what about TI, EAI

4.80 Additional studies sponsored by utilities other than Consolidated Edison are being carried out on the Hudson River to assess the impacts of entrainment and impingement and related matters. Further, New York State Department of Environmental Conservation, through the U.S. Department of Commerce, has underway a 3-year striped bass tagging program to determine the contribution of the Hudson River striped bass to the Mid-Atlantic fishery. An Inter-Utility Coordinating Committee has been established to coordinate the efforts of several utilities conducting studies on the Hudson River.

completed?

4.81 Several factors have greatly hindered the effort to assess adequately the cumulative impacts of power generation activities along the Hudson river estuary during the preparation of the draft environmental statement. Primary among these was the lack of adequate synthesis of the considerable data that had been gathered. Too much important information was available only in annual data report form with little analysis for trends or insight into system structure and function that should emerge from multi-year data. Also, many

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important data apparently were available but had not been worked up into a form useful for consideration in decision-making. Recent publications prepared for the Utilities have helped to alleviate this problem (Orange and Rockland, 1977; Central Hudson Gas and Electric, 1977; Lawler, 1978).

what about Con Edison

way out of date

4.82 Contributing to the problem of data synthesis has been the fragmented research approach of considering individual power plants in isolation of each other. Only recently have some efforts been initiated to study the Hudson River estuary from a more holistic point of view (Multiplant Impact Study being conducted by Texas Instruments and the Hudson River Study being carried out by Lawler, Matusky, and Skelly), but these studies still have been oriented strongly toward striped bass alone.

Upland Ecosystems

4.83 Natural upland ecosystems are potentially altered or eliminated by construction and operation of power plants in the Hudson River Valley. Operation of cooling towers would result in salt drift, introducing the possibility of vegetation damage occuring in the vicinity of the towers.

Bowline Point Generating Station

4.84 The Orange and Rockland property containing the Bowline generating station is 245 acres. Of this total, Bowline Pond is 53 acres and 192 acres are uplands. Construction of the plant included the filling of about 60 acres of wetlands along Minisceongo Creek. The net effect of plant construction on the site has been to displace all species except those capable of adapting to the mix of urban, suburban, and industrial land use typical of the site and the Haverstraw area. The power plant was connected to an existing transmission corridor by using a 3.4-mile underground transmission line.

4.85 Potential Salt Drift From Cooling Towers. If closed-cycle cooling is required at Bowline Point in the future, the potential exists for damage to vegetation from salt drift produced by cooling towers during the months when river water used for make-up is saline. Although the term "salt drift" is a misnomer, it has been used consistently for decades; the effect of brackish water droplets to plants is due principally to the chloride ion (Boyce, 1954).

4.86 Several factors limit the ability to estimate the potential for damage to vegetation from salt drift from cooling towers at Bowline Point. The acute effect of salt drift from cooling towers on vegetation has only recently become the subject of research. Only two studies reported in scientific journals or other publications have produced reliable data on the response of vegetation to salt

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Reference Indian Point Studies?

drift (McCune et al., 1977; Silberman and McCune, 1978). In these studies, only eleven species of trees and shrubs were tested, only one exposure interval (either 4 or 6 hours) was used for each species, and only seedlings and saplings of nursery stocks were exposed. The response of indigenous and mature plants may be different, and deposition rate response may not be directly proportional to length of exposure. Salt drift impacts to herbs and to flowering and fruiting have not been studied. No data are available for more than 200 species of plants in the Bowline Point area.

need that — large number?

4.87 Rates of salt drift deposition at Bowline Point were estimated for 1964-5, 1974, and 1978 at 0.1 mile intervals to a distance of 2.0 miles from the site of the proposed towers using a computer model (see Appendix E). 1964-5 was selected as representative of a drought year. Hourly meteorological data for 1974 and 1978 (wind speed and direction at 200 or 350 feet, relative humidity, and temperature) and river salinities in conjunction with a cooling tower salinity concentration factor of 2.4 were inputs to the model (McLain, 1979). Since onsite meteorological data are not available for 1964-5, deposition rates for that period were calculated by multiplying 1978 rates by 1964-5:1978 monthly salinity ratios (Table 4-A) (salinity data were available for October-December 1964 and January -September 1965). Isopleths of 1964-5, 1974, and 1978 mean monthly deposition due to the Bowline Point facilities alone are presented in Appendix E.

4.88 Total salt deposition at Bowline Point would also include drift from proposed towers at Indian Point and natural drift mostly from the Hudson River. Maximum, mean monthly, total solute deposition that would result within one mile of Bowline Point from the proposed Indian Point cooling towers (Table 4-15) was estimated using deposition estimates for 1977 (Environmental Systems Corporation, 1978) in conjunction with 1964-5:1978 salinity ratios at Bowline Point. Maximum, mean monthly, natural total solute deposition within one mile of the proposed Bowline Point towers (Table 4-15) was extrapolated from in-situ measurements by Mulchi et al. (1976) and salinity data in Mulchi et al. (1976) and Orange and Rockland Utilities, Inc. (1977).

4.89 Maximum mean monthly total salt drift deposition rates at selected intervals from the site of the proposed towers at Bowline Point are given in Table 4-16 (isopleths in Appendix E do not incorporate the additional salt deposition from natural sources and from towers at Indian Point if they are constructed). Maximum total deposition rates were used to assess potential effects on vegetation.

4.90 Acute No-Visible-Effect Levels for Plants. The Acute No-Visible-Effect Level (ANVEL) of salt deposition for each species tested by McCune et al. (1977) and Silberman and McCune (1978) is presented in Table 4-17. Flowering dogwood, white ash, and Canadian

TABLE 4-15

BOWLINE POINT MEAN MONTHLY 1964-5:1978 SALINITY RATIOS, MAXIMUM POTENTIAL DEPOSITION RATES CAUSED BY PROPOSED INDIAN POINT COOLING TOWERS, AND MAXIMUM NATURAL TOTAL SOLUTE DEPOSITION RATES

MONTH	1964-5: 1978 SALINITY RATIO[a]	MAXIMUM POTENTIAL TOTAL SOLUTES DEPOSITION FROM PROPOSED INDIAN POINT TOWERS[b] (kg/ha/mo)	MAXIMUM AVERAGE NATURAL TOTAL SOLUTES DEPOSITION[c] (kg/ha/mo)
January	53.90	3.935	0.91
February	0.36	0.026	0.91
March	2.20	0.161	0.91
April	1.00	0.073	0.91
May	9.50	0.694	0.91
June	4.82	0.352	0.91
July	1.14	0.083	0.91
August	1.34	0.098	0.91
September	1.16	0.085	0.91
October	3.04	0.222	0.91
November	2.29	0.167	0.91
December	1.47	0.107	0.91

[a] Source: Dr. Howard McClain, Oak Ridge National Laboratory, Personal Communication, December 1979.

[b] Source: Estimated using Environmental Systems Corporation (1978) projection for 1977 and 1964-5:1978 SALINITY RATIOS AT Bowline Poine.

[c] Extrapolated using in-situ measurements by Mulchi et al. (1976) and salinity data in Mulchi et al. (1976) and Orange and Rockland Utilities, Inc. (1977).

TABLE 4-16

MAXIMUM, MEAN MONTHLY, TOTAL SALT DEPOSITION RATES (kg/ha/mo) FOR 1964-5, 1974, AND 1978 AT SELECTED INTERVALS (MILE) FROM THE PROPOSED BOWLINE POINT COOLING TOWERS

	1964-5			1974	1978
MONTH	0.2 mile	0.3 mile	0.9 mile	0.2 mile	0.2 mile
January	47.9	30.4	8.0	6.4	5.5
February	2.2	1.8	1.0	2.0	3.6
March	4.8	3.5	1.3	1.7	1.8
April	1.5	1.3	1.0	1.7	1.5
May	9.1	5.0	2.1	2.1	2.0
June	45.5	20.8	3.5	6.0	9.8
July	46.5	20.8	6.0	1.5	38.8
August	36.6	20.9	6.1	1.5	25.9
September	55.0	28.5	8.2	4.2	44.2
October	82.5	48.8	6.1	9.1	25.9
November	134.8	77.2	10.1	1.9	55.3
December	39.9	27.7	4.3	1.1	8.3

TABLE 4-17

ACUTE NO-VISIBLE-EFFECT LEVELS (ANVEL's) (kg/ha/mo) OF TOTAL SOLUTES DEPOSITED ON NINE DECIDUOUS AND TWO EVERGREEN PLANT SPECIES IN GREENHOUSE AEROSOL EXPOSURE CHAMBERS

SPECIES	kg TOTAL SOLUTES/ HECTARE/MONTH
Tsuga canadensis Canadian Hemlock	10.2[a]
Fraxinus americana White Ash	<91.4[b] (Effective Dose which affected 50% of test organisms (ED50) = 183.0[a])
Cornus florida Flowering Dogwood	91.4[a,b] (ED50 = 254.0[a])
Pinus strobus White Pine	914.4[b]
Forsythia intermedia Forsythia	<1828.8[b]
Quercus prinus Chestnut Oak	1828.8[b]
Robinia pseudo-acacia Black Locust	1828.8[b]
Albizia julibrissin Mimosa	1828.8[b]
Acer rubrum Red Maple	1828.8[b]
Koelreutaria paniculata Golden Rain Tree	5486.4[b]
Hamamelis virginiana Witch Hazel	7315.2[b]

[a] Source: Silberman and McCune, 1978.
[b] Source: McCune et al., 1977.

hemlock are from 20 to 200 times more sensitive than the other species tested. Original values (micrograms $Cl^-/cm^2/4$ or 6 hours) have been converted to kg total solutes/ha/mo for convenience using composition values of Hudson River water at Indian Point (McCune et al. 1977).

4.91 When using ANVEL's and mean monthly deposition rates to assess species effect, it must be assumed that these rates are directly proportional to time and, therefore, directly proportional to each other. The corollary assumption is that the length of exposure is irrelevant to effect. These assumptions have not been confirmed.

4.92 Vegetation in the Vicinity of Bowline Point. Since reliable data are available only for tree and shrub species, herbaceous vegetation was not studied during a two-day reconnaissance of the site. Trees within 0.3 mile of the proposed towers are found mostly on stream and ditch banks, along roadsides, and in parklands. Dominant trees are red maple (Acer rubrum), black locust (Robinia pseudoacacia), tree-of heaven (Ailanthus altissima), weeping willow (Salix babylonica), gray birch (Betula populifolia, and sycamore (Platanus occidentalis). None of the other species listed in Table 4-C were observed. Remaining terrestrial habitats are occupied predominantly by herbaceous old field communities and reed (Phragmites australis) dominated marshes.

4.93 The 0.3-0.9 mile interval is similar to the 0.0-0.3 mile segment with the addition mostly of residential plantings of ornamentals such as flowering dogwood, white pine, forsythia, and mimosa (silk tree). Natural stands of Canadian hemlock do not occur within 0.9 mile of the proposed towers.

4.94 South Mountain-High Tor State Park is located 0.9 mile from the proposed towers. The 700 foot-high mountain is almost completely forested and is generally characterized by mixed deciduous communities. Common canopy species include tulip poplar (Liriodendron tulipifera), black birch (Betula lenta), red maple sugar maple (A. saccharum), red oak (Quercus rubra), black oak (Q. velutina), white ash (Fraxinus americana) and hickories (Carya spp.). Subcanopy dominants include flowering dogwood, witch hazel (Hamamelis virginiana), and striped maple (A. pennsylvanica).

4.95 Potential Acute Impacts to Vegetation at 1974 and 1978 Deposition Rates. None of the species tested would be visibly, acutely affected by 1974 or 1978 maximum, mean monthly, deposition rates as estimated by the computer model (see Appendix E). The highest 1974 rate (9.1 kg/ ha/mo, Table 4-16) would have been 1.1 kg/ha/mo less than the ANVEL of the most sensitive species, Canadian hemlock (Table 4-17). Although the greatest 1978 rate, which would have occurred within 0.2 mile of the proposed tower in November, exceeds the ANVEL of Canadian hemlock and possibly white ash, neither species was observed within a 0.3 mile radius during the site visit. Also white ash would not have leaves in November. The greatest rate in the growing season (44.2 kg/ha/mo) would have been less than one-half of the maximum possible ANVEL for white ash and one-fourth of the rate that injured 50 percent of test organisms.

4.96 Potential Acute Impacts to Vegetation at Drought Year Deposition Rates (1964-5). Of the species tested, only red maple and black locust were observed within 0.3 mile of the proposed tower. Neither would probably be visibly, acutely affected at the estimated 1964-5 deposition rates since ANVEL's for these species are 14.6 times greater than the highest deposition rate that would have occurred at 0.2 mile.

4.97 Canadian hemlock trees growing within 0.3-0.9 mile of the proposed towers could have been visibly affected in 1964-5. Deposition rates during July through December exceeded the ANVEL for Canadian hemlock.

4.98 None of the eleven species tested would be affected by 1964-5 deposition rates beyond 0.9 miles, i.e., within the South Mountain-High Tor State Park forest. Four species are common in the canopy (red maple, white ash) and subcanopy layers (flowering dogwood, witch hazel) of the State Park. However, the total number of species in the South Mountain-High Tor State Park area probably exceeds 200. The effect of salt drift on these species, excluding the four above, is unknown.

4.99 Potential Chronic Salt Drift Impacts to Vegetation. Chronic impacts of salt drift to vegetation are unknown (Talbot 1979). Patterson et al. (1977) have obtained data that suggest that Cl^- and Na^+ may bioaccumulate in leaves of dogwood, black locust, sassafras (Sassafras albidum) and scrub pine (Pinus virginiana). This finding may suggest that threshold levels could be attained or productivity reduced as a result of long-term salt drift exposure. The authors suggest that dogwood may be utilized as a good bioindicator of ion accumulation in plants.

4.100 Potential Salt Drift Impacts to Fauna. The direct physiological effect of salt drift to vertebrates has not been studied but is generally considered to be negligible due to their capacity to regulate body salt (Talbot 1979). Effects to other animals have not been reported. If salt drift alters plant community structure or productivity, fauna would be affected indirectly by loss of food supply or alteration of habitat.

Roseton Generating Station

4.101 The Central Hudson Gas and Electric property containing the Roseton generating station is 133 acres, formerly the site of a brick works. Construction of the Roseton plant included completion of the filling of a small pond that had been the site of fly ash dumping from the adjacent Danskammer plant (F. Dooris, 1977). Because of the character of the previous use of the site, the net effect of plant construction and operation on the existing terrestrial ecosystems is small.

4.102 Potential Salt Drift from Cooling Towers. If closed-cycle cooling is required at the Roseton generating station damage to vegetation from salt drift could result. Potential rates of salt drift deposition at Roseton were estimated for 1964-5, 1974, and 1978 in the same manner as for Bowline Point with the exception of excluding drift from Indian Point since these towers would not contribute to deposition at Roseton. Isopleths of mean monthly deposition due to the proposed Roseton towers are presented in Appendix E. Maximum, mean monthly, total salt drift deposition rates (Roseton tower rates plus natural deposition) at selected intervals from the proposed towers are listed in Table 4-18. These rates were used in conjunction with the acute no-visible-effect levels (ANVEL) to assess potential vegetation effects.

4.103 Vegetation in the Vicinity of Roseton. About 40 percent of the land within 0.3 mile of the proposed towers is forested. Most of the forest occurs on a 240 foot-high east-facing slope. Common canopy trees are red oak, black oak, white oak, striped maple, sugar maple, red maple, tree-of-heaven, butternut hickory, pignut hickory, black birch, white ash, tulip poplar, and beech. Less than ten Canadian hemlocks were observed during the site reconnaissance. Flowering dogwood and witch hazel are common in the subcanopy.

4.104 More than 75 percent of the land between 0.3 and 0.6 mile of the proposed towers is forested. Species composition is similar to the east-facing slope described above with the exception of the northwest-facing slope adjacent to the Cedar Hill Cemetery. This slope possesses dense natural stands of Canadian hemlock; maples, black birch, and beech are also common.

4.105 Less than half of the cemetery is located within 0.6 mile of the proposed towers. Many ornamentals such as dogwood, weeping willow, spruce, pine, and Canadian hemlock are maintained.

4.106 About 16.5 acres of apple orchard occur 0.5-0.6 mile west of the proposed towers. The orchard extends well beyond the 0.6 mile interval.

TABLE 4-18

MAXIMUM, MEAN MONTHLY, TOTAL SALT DEPOSITION RATES (kg/ha/mo) FOR 1964-5, 1974, AND 1978 AT SELECTED INTERVALS (MILE) FROM THE PROPOSED ROSETON COOLING TOWERS

	1965			1974	1978	
MONTH	0.2 mile	0.3 mile	0.4 mile	0.2 mile	0.2 mile	0.3 mile
January	3.9	2.9	2.2	1.8	1.8	1.5
February	2.3	1.7	1.3	1.9	2.3	1.7
March	1.9	1.5	1.2	1.6	1.9	1.5
April	1.5	1.2	1.1	1.6	1.5	1.2
May	1.6	1.2	1.1	1.5	1.6	1.2
June	9.6	10.2	5.8	1.8	2.0	1.4
July	29.3	13.4	7.5	1.8	14.6	6.9
August	19.7	9.1	5.4	1.8	4.0	2.3
September	11.0	5.4	3.4	1.8	3.0	1.9
October	27.4	15.8	9.5	2.0	1.8	1.4
November	23.4	14.3	8.9	1.8	1.8	1.4
December	3.1	2.3	1.7	1.8	1.8	1.4

4.107 Potential Acute Impacts to Vegetation at 1974 and 1978 Deposition Rates. Five of the eleven species tested for salt drift effects (red maple, white ash, Canadian hemlock, dogwood and witch hazel) occur within 0.2 miles of the proposed towers but would not have been acutely, visibly affected in 1974 or 1978 (Tables 4-17 and 4-18).

4.108 Potential Acute Impacts to Vegetation at Drought Year Deposition Rates (1964-5). The ANVEL of Canadian hemlock would have been exceeded only to a distance of less than 0.4 mile in 1964-5 (Table 4-17 and 4-18). Fewer than 10 solitary hemlocks were observed less than 0.4 mile of the proposed towers during the site reconnaissance. The natural stands of hemlock adjacent to the cemetery would not have been affected since they are 0.4 mile from the proposed towers. Red maple, white ash, dogwood, and witch hazel would not have been visibly, acutely affected at any interval. ANVEL's for the remaining 200 or more indigenous species are not known. The potential impact of salt drift to the orchard is not known since apple trees have not been tested for the effects of salt drift. Similarly, the possible salt drift effect to almost all ornamental species in the cemetery cannot be projected.

4.109 Potential Chronic Salt Drift Impacts to Vegetation and Fauna. As described in previously, chronic effects of salt drift to vegetation are unknown. Direct effects on vertebrates are unlikely due to their osmoregulatory capacity. Direct impacts on other animals are not known. Indirect effects due to changes in habitat are possible.

Cumulative Impact of All Generating Stations

4.110 Presently existing power plants along the Hudson River occupy about 1500 acres of land. Proposed facilities would probably require about an additional 1500 acres. The impact of these facilities on upland ecosystems will vary from site to site depending on previous use and condition of the land. In general, the changes that would occur are most likely to be similar to those described above for Bowline and Roseton. The overall land area devoted to power plants would be a small percentage of the total land area of the Hudson River Valley.

which plants included

Wetland Ecosystems

4.111 Construction of power plants along the shores of the Hudson River estuary could potentially affect wetland ecosystems by filling for use in the construction of necessary facilities and by modification of upland runoff patterns.

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Bowline Point Generating Station

4.112 Construction of the Bowline Point Generating Station resulted in the loss to filling of about 60 acres of wetlands along Minisceongo Creek. The creek channel was also relocated to empty directly into the Hudson River at a point adjacent to the fuel storage area, diverting it from the Gassy Point Marsh to the North (see Figure 1-3). The wetland community covered with fill has been completely lost. The effect of the creek diversion on Grassy Point Marsh is unknown, but some moderate alteration is likely to have occurred because of the changed water relationships.

Roseton Generating Station

4.113 Construction of the Roseton station did not alter wetlands in the area (F.Dooris, 1977).

Cumulative Impact of All Generating Stations

4.115 The area of wetlands involved in construction of the older 59th Street, Lovett, Danskammer, and Albany stations is unknown. Wetlands eliminated at Bowline and Roseton totalled about 60 acres. No wetlands were involved at Indian Point. Required compliance with New York State wetland protection legislation, Section 404 of the Federal Water Pollution Control Act Amendments of 1972, and Section 10 of the River and Harbor Act of 1899 should minimize effects of future power facilities on wetlands along the Hudson River.

Aquatic Ecosystems

4.115 The aquatic ecosystem of the Hudson River estuary can be affected by power plant operation through discharges of heated water and by entrainment and impingement of organisms. Chemical contaminants discharged from the power plants are not expected to have detrimental effects on aquatic ecosystems. Extensive field measurements have been made by the utilities to determine the effects of presently operating stations and to provide a baseline for predicting the impacts of future power plants to be operated on the river. Much of this effort has focused on the striped bass because of its recreational and commercial importance in the region. Simulation models have been developed to help predict the long term effect on this population.

Impacts of Bowline Point Generating Station

1979-1980

4.116 Data are available for the years 1971 through 1977 for assessing the impact of the Bowline Units 1 and 2 on the aquatic ecosystem of the Hudson estuary in the vicinity of Bowline Point.

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The data include the effects of the operation of Unit 1 since 1972 and Unit 2 since 1974. The following discussion draws on data given in Lawler, Matusky, and Skelly (1974, 1975a, 1976a, 1978), Ecological Analysts (1976a), and Orange and Rockland (1977).

4.117 Phytoplankton. The applicant has assessed entrainment and thermal discharge effects on phytoplankton by comparing abundance, species composition, and the rate of primary production in the intake area of Bowline Pond and in the discharge area in the adjacent river (Lawler, Matusky, and Skelly, 1975b, 1976a, 1978; Orange and Rockland, 1977). No significant differences were found in mean abundance between the intake vicinity and the discharge areas. Diatom abundance significantly was different, but abundance patterns were different from year to year (diatoms more abundant at discharge than intake in 1973 and 1975 with the reverse being found in 1974), suggesting that these differences may have been due more to different evironmental conditions in the river and Bowline Pond than to the effects of entrainment. Considerable seasonal variation has been observed in phytoplankton abundance, but no long term trend has been found to correlate with plant operation in the Bowline area.

4.118 No gross effects on primary productivity were found based on intake-discharge comparisons (Orange and Rockland, 1977). Reductions in primary productivity appeared to range from 10 to 20 percent but these apparent differences may have resulted from intake sampling techniques.

4.119 Presently available data do not indicate any significant impact of the power plant on phytoplankton in the Bowline vicinity. The absence of any long term trends over the years in phytoplankton abundance suggests a lack of plant-induced changes in the Bowline Point vicinity. Short generation times of phytoplankton and rapid recycling of nutrients contained in any algal cells killed by entrainment may tend to minimize any effects.

4.120 Zooplankton. Studies on the distribution and abundance of microzooplankton during the years 1972-1977 have shown no spatial or temporal distribution patterns which suggest significant effects of power plant entrainment at the population or community levels (Orange and Rockland, 1977; Lawler, Matusky and Skelly 1978). Entrainment survival studies showed that microzooplankton generally sustained entrainment mortalities averaging 4 to 17 percent in 1975 and 1976 (See Table 4-19 for sample data). Microzooplankton entrainment mortality was independent of temperatures below 37 C, the highest temperature examined. Laboratory investigations of thermal tolerance in major microzooplankton species indicates that substantial entrainment mortality should occur only under full-load and/or reduced pump-flow conditions, except for the most thermally sensitive species.

TABLE 4-19

ENTRAINMENT MORTALITY OF ZOOPLANKTON (PERCENT) AT BOWLINE GENERATING STATION. NUMBERS ARE DIFFERENCES IN INITIAL SURVIVAL BETWEEN INTAKE AND DISCHARGE SAMPLES.

SPECIES	July 29 - August 5, 1975 Temp. 28C ΔT 8C	September 29 - October 1, 1975 Temp. 20C ΔT 7C	December 16 - December 17, 1975 Temp. 6C ΔT 6C	SUMMARY FOR 1975
TOTAL MICROZOOPLANKTON	21	--	21	12
Keratella cochlearis	—	--	--	--
Coperod mauplii	19	--	29	--
Eurytemora affinis	25	--	39	--
Acartia tonsa	--	*	--	--
Halicyclops fosteri	12	--	--	--
Bosmina longirostus	27	--	39	22
TOTAL MACROZOOPLANKTON	--	15	--	--
Monoculodes edwardsi	--	--	--	--
Gammarus daiberi	--	--	--	--
Edotea triloba	--	--	--	--
Neomysis americana	--	--	--	--
Chaoborus punctipennis	--	--	--	--

*No organisms of this species collected.

-No significant difference found between intake and discharge survival.

Source: Ecological Analysts, 1976a.

4.121 Studies of the distribution and abundance of macrozooplankton conducted from 1972 to 1977 have demonstrated no significant effects of power plant entrainment at the population or community level (Orange and Rockland, 1977; Lawler, Matusky, and Skelly, 1978). Entrainment survival studies showed that macrozooplankton tend to be less susceptable to entrainment mortality than microzooplankton, and averaged less than 5 percent mortality (see Table 4-19 for sample data). However, the mysid Neomysis americana sustained substantial mortality at discharge temperatures in excess of 32 C. Latent mortalities of macrozooplankton were insignificant at discharge temperatures below about 25 C, but increased with discharge temperatures from 25 to 35 C. Thermal tolerance laboratory investigations predicted that effects of thermal stress would be negligible under most conditions for most species entrained. However, Neomysis americana is predicted to sustain substantial or total mortality under most daytime operational modes during the summer months. During reduced-load nighttime operation (when involvement is maximum) no entrainment mortality is expected.

4.122 Benthic Animals. Benthic communities normally exhibit considerable temporal and spatial variation in abundance and species composition. Studies of benthic communities in the Bowline Point area from 1972 to 1976 indicated no significant effects on the benthos that could be directly attributed to power plant generation. No effects on the benthic community in the Bowline vicinity attributable to the thermal plume are evident from the available data. Observed differences among sample stations were more likely to be due to other environmental and physical factors, such as salinity changes, season of the year, and depth. Plume surveys and bottom temperatures taken when benthic samples were gathered indicate that the thermal discharge rises to the river surface. Where bottom communities in the discharge vicinity experience any temperature increase at all, it is apparently only 1 to 3 F. Such a small temperature difference is unlikely to affect benthic animals directly to any significant extent.

4.123 Other factors that may affect the benthic community include scouring of the bottom near the intakes and the discharge ports and loss of planktonic larvae by entrainment mortality. Planktonie larvae of the dipteran Chaoborus punctipennis are the only benthic organisms for which entrainment data are available. No entrainment mortality was statistically discernible. Other species are not likely to be seriously affected.

4.124 Entrainment of Fish Eggs, Larvae, and Juveniles. The abundance of fish eggs and larvae is generally greater in the Hudson River proper than in Bowline Pond, where the cooling water intake for the Bowline Point Plant is located. Entrainment sampling has been carried out using collecting devices at the plant intake and discharge to estimate the types and numbers of organisms carried through the plant. Fish eggs, larvae, and juveniles small enough to pass through the traveling intake screen (0.95 cm or 3/8 inch) are entrained with the cooling water passing through the condenser and then are discharged back into the Hudson River (see Figures 1-2, 1-7, and 1-8). The primary factors that may cause adverse effects to entrained organisms are mechanical and thermal shock. The quantity of organisms entrained changes with seasonal variation in the abundances of fish eggs and larvae occurring in surrounding waters.

4.125 In addition to the quantity of organisms entrained, the rates of immediate and latent entrainment mortality must be considered in assessing the significance of entrainment. Sublethal effects of passage through the power plant may also be important but are not well known. The immediate effects of entrainment are assessed through the observation of organisms collected from the plant discharge. Because plant conditions vary depending on operational load, season, and equipment used, entrainment mortality varies through time. To assess the long range effects of power plant entrainment, the loss due to entrainment must be compared to species standing stocks.

4.126 It is difficult to measure accurately the numbers of eggs, larvae, and juveniles entrained by a power plant. When nets are used to sample entrained organisms, the major sampling problems include net avoidance, clogging of nets, extrusion of eggs and larvae, and inaccurate measurement of the water volume sampled. Sampling with a pump and larval table alleviates some of the problems associated with net sampling but pumps may damage larger juveniles and fragile yolk-sac larvae. Ecological Analysts (1976, 1977) have documented the sampling differences that occur between the pump-larval table method and net systems. At the Bowline Point Plant, entrainment rates have generally been estimated using net samplers, while entrainment survival was studied using the pump-larval table method. In an assessment of ichthyoplankton sampling programs used at Hudson River power plants, Carpenter (undated), an Environmental Protection Agency consultant, concluded that the Bowline sampling methods would tend to underestimate entrainment of fish eggs, larvae, and juveniles. The magnitude of the bias was not estimated, however.

4.127 The following discussion is based largely on studies conducted during 1977. These results are generally also representative of data collected during 1973-1976 (Orange and Rockland, 1977). Larvae of the bay anchovy were dominant among entrained fish at the Bowline Point Power Plant in 1977, accounting for nearly 70 percent of the total (see Table 4-20). Atlantic tomcod, striped bass, and

TABLE 4-20

ICHTHYOPLANKTON COLLECTED DURING ABUNDANCE SAMPLING AT THE BOWLINE POINT PLANT DISCHARGE DURING 1977

SPECIES	LIFE STAGE	NUMBER COLLECTED	PERCENT COMPOSITION
Bay anchovy	Larvae	13,375	69.8
Atlantic tomcod	Yolk-sac larvae	2,366	12.3
Striped bass	Larvae	763	4.0
Unidentified[a]	Larvae	485	2.5
White perch	Egg	405	2.1
Bay anchovy	Juvenile	258	1.3
Clupeids	Larvae	248	1.3
White perch	Larvae	227	1.2
<u>Morone</u> spp.	Larvae	214	1.1
Silversides	Larvae	145	0.8
Striped bass	Juvenile	135	0.7
Hogchoker	Larvae	108	0.6
Atlantic tomcod	Larvae	70	0.4
Clupeids	Egg	69	0.4
American eel	Junenile	52	0.3
Striped bass	Yolk-sac larvae	33	0.2
Bay anchovy	Egg	30	0.2
Rainbow smelt	Larvae	22	0.1
Sunfish	Larvae	20	0.1
White perch	Juvenile	19	0.1
Northern pipefish	Juvenile	16	0.1
Atlantic silverside	Larvae	14	0.1
Atlantic tomcod	Juvenile	10	0.1
Unidentified[a]	Egg	9	0.0
Rainbow smelt	Juvenile	8	0.0
Clupeids	Juvenile	7	0.0
White perch	Yolk-sac larvae	7	0.0
Tessellated darter	Yolk-sac larvae	7	0.0
Minnows	Larvae	6	0.0
American shad	Larvae	4	0.0
Hogchoker	Juvenile	4	0.0
Unidentified[a]	Juvenile	4	0.0
Killifish	Larvae	4	0.0
Killifish	Juvenile	3	0.0
Clupeids	Yolk-sac larvae	3	0.0
Hogchoker	Yolk-sac larvae	3	0.0
Weakfish	Juvenile	2	0.0
Silversides	Juvenile	1	0.0
Striped bass	Egg	1	0.0
Winter flounder	Larvae	1	0.0
Yellow perch	Yolk-sac larvae	1	0.0
Unidentified	Egg	1	0.0
Atlantic tomcod	Egg	1	0.0
Walleye	Larvae	1	0.0
Weakfish	Larvae	1	0.0
Cyprinids	Yolk-sac larvae	1	0.0
Unidentified	Yolk-sac larvae	1	0.0

[a] Indicates that organisms were damaged; 54 percent of the damaged larvae occurred during the period of peak bay anchovy abundance (after 6 July). Abundance of species other than bay anchovy in samples collected during this period was very low. Other damaged organisms were collected throughout the sampling period when striped bass, white perch, clupeids, and bay anchovy were abundant.

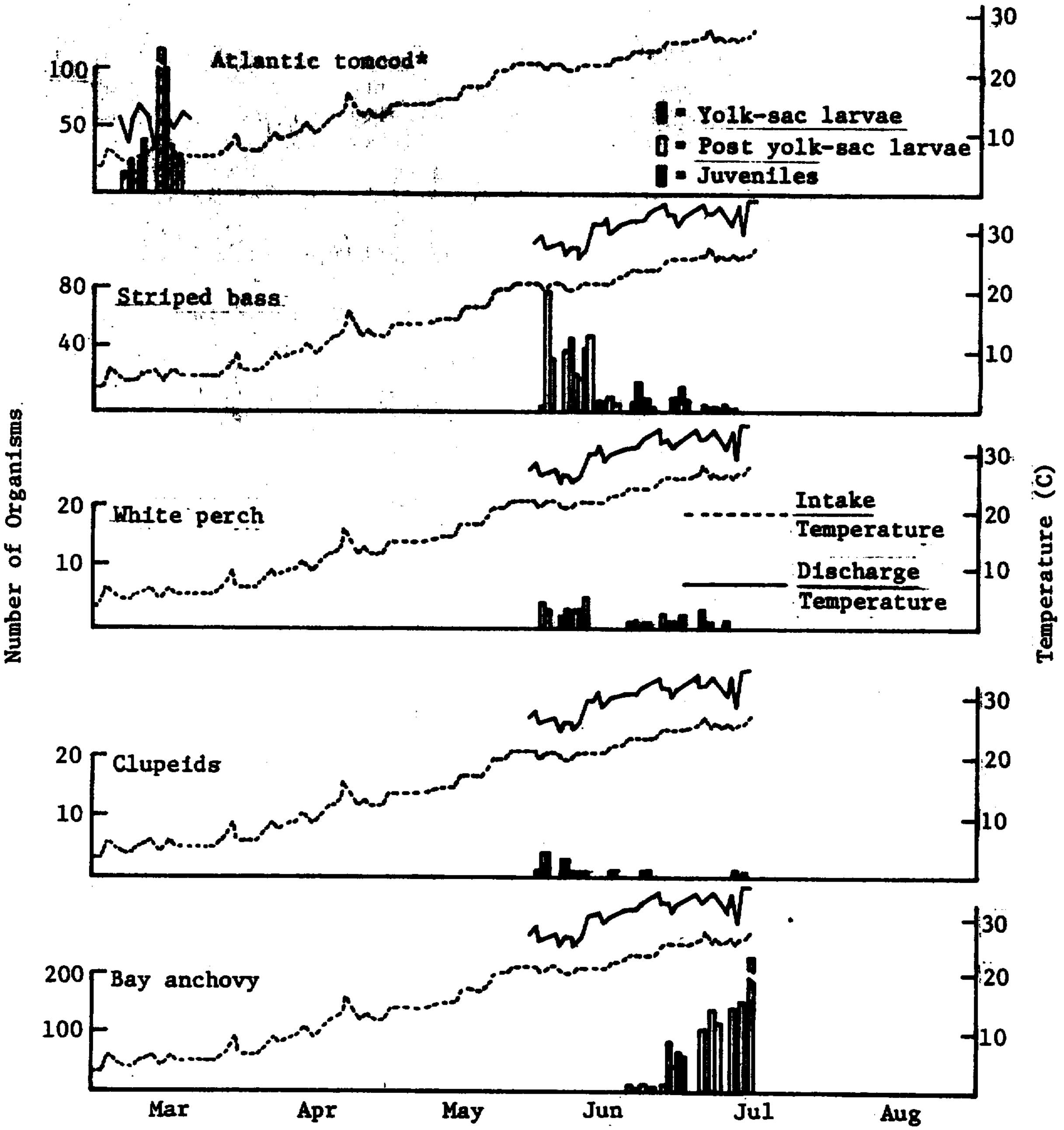
Source: Ecological Analyst, 1978a.

white perch were also entrained in relatively large numbers, in total accounting for another 18% of entrained fish. As a result of the time of spawning for these species, the tomcod was primarily entrained during the month of March, while striped bass, white perch, and bay anchovies were entrained during June and July (see Figure 4-3).

4.128 Entrainment mortality at the Bowline Power Plant has been estimated through comparison of survival rates in fish collected at the plant intake and discharge. Intake survival has been used as a control because organisms collected at the intake had not been entrained but had been subjected to sampling and handling stress. The entrainment survival percentages (proportion surviving at intake divided by proportion surviving at discharge times 100) for dominant entrained fish species in 1977 are presented in Table 4-21. Although the following discussion is based largely on 1977 data, studies carried out in 1975-1976 show the same general results (Orange and Rockland, 1977).

4.129 Initial entrainment survival for striped bass, white perch, and clupeids is generally greater than 50 percent for discharge temperatures below 30 C. At higher temperatures, entrainment survival is generally low. The yolk-sac larvae of the Atlantic tomcod consistently showed high initial survival (84 to 85 percent). Entrainment survival in the bay anchovy is difficult to assess because this species is apparently sensitive to handling and shows very high mortality even in intake samples (Orange and Rockland, 1977). In most species studied, entrainment mortality appears to be related primarily to thermal stress (Ecological Analysts, 1978b) and, there fore, is dependent on the operational conditions of the plant. Latent entrainment survival measured after 96 hours is less than initial survival, but this is difficult to assess because substantial mortality occurs in control (intake) as well as discharge samples that are held to estimate latent mortality.

4.130 Utilities and their consultants have calculated estimates of entrainment-related loss of fish eggs, juveniles, and larvae based on species standing crops, rates of entrainment, and survival ratios. These estimates are expressed as the number of larvae killed by entrainment in a given year divided by the standing crop of the larvae between River Mile 30 and River Mile 50. Losses for the following species have been estimated:



*Tomcod spawned in February would not appear in March samples.

FIGURE 4-3
SEASONAL DISTRIBUTION OF ICHTHYOPLANKTON COLLECTED AT THE BOWLINE POINT PLANT DURING 1977

TABLE 4-21

ENTRAINMENT SURVIVAL OF ICHTHYOPLANKTON AT THE BOWLINE POINT PLANT DURING 1977

SPECIES	YOLK-SAC LARVAE		POST-YOLK SAC LARVAE		JUVENILES	
	TEMPERATURE (C)	PERCENT SURVIVAL	TEMPERATURE (C)	PERCENT SURVIVAL	TEMPERATURE (C)	PERCENT SURVIVAL
Striped bass	20.0-29.9	--	20.0-29.9	97 (NS)	20.0-29.9	90 (NS)
	30.0-32.9	--	30.0-32.9	100 (NS)	30.0-32.9	90 (NS)
	33.0-35.9	--	33.0-35.9	41	33.0-35.9	43
White perch	20.0-29.9	--	20.0-29.9	62	20.0-29.9	--
	30.0-32.9	--	30.0-32.9	16	30.0-32.9	--
	33.0-35.9	--	33.0-35.9	48	33.0-35.9	--
Clupeids	20.0-29.9	--	20.0-29.9	51 (NS)	20.0-29.9	--
	30.0-32.9	--	30.0-32.9	--	30.0-32.9	--
	33.0-35.9	--	33.0-35.9	--	33.0-35.9	--
Bay anchovy	20.0-29.9	NE	20.0-29.9	NE	20.0-29.9	--
	30.0-32.9	NE	30.0-32.9	NE	30.0-32.9	--
	33.0-35.9	NE	33.0-35.9	NE	33.0-35.9	--
Atlantic tomcod	5.5-13.9	84	5.5-13.9	--	5.5-13.9	--
	14.0-17.9	85 (NS)	14.0-17.9	--	14.0-17.9	--

Note: Dashes indicate less than five organisms collected at the intake or discharge.
(NE) indicates that no estimate of entrainment survival was made.
(NS) indicates survival at the discharge not significantly lower than that at the intake for a one-tailed z-test at the $\alpha = 0.05$ level.

SPECIES	PERCENT LOSS TO STANDING CROP FROM ENTRAINMENT[a] 1974	1975	SOURCE
White Perch	0.37	1.61	Orange and Rockland (1977)
Striped Bass	2.55	2.95	McFadden (1977)
Alosa spp. (herring)	0.03	0.09	Orange and Rockland (1977)

[a] Standing crop between River Mile 30 and River Mile 50.

Quantitative estimates have not been made for other species affected such as the bay anchovy and Atlantic tomcod.

4.131 Fish Impingement. The Bowline Point Station intake structure is divided into six bays, three for each of the two generating units (see Chapter 1). A traveling screen and screenwash pump system is used in each bay for cleaning the screen with a spray of water. The traveling screens are constructed of 0.95 cm (3/8 inch) mesh to prevent larger fish or debris from passing through the plant with the cooling water. Materials retained on the screen are removed by the spray of water and discharged on the northeast side of the intake. When impingement sampling is carried out, fish retained on the screen are sorted from the debris and collected for study. A sampling program for impinged fish was initiated in December 1972 and has continued at a minimum of once a month to the present. Since 1974, impingement sampling has been performed at least once per week, and data are now available for samples taken through December 1977.

4.132 A total of about 60 fish species have been impinged at Bowline Point. Based on the five years of data presented in Table 4-22, impingement was dominated by white perch (60.5 percent average), with striped bass (8.4 percent average), blueback herring (7.0 percent average), rainbow smelt (6.0 percent average) alewife (5.4 percent average), and Atlantic tomcod (3.5 percent average) also impinged in substantial numbers. Weakfish, bluefish, and bay anchovy may also be impinged in years when salt intrusion causes river conditions in the vicinity of the plant to favor these marine species.

4.133 Estimates of total numbers of fish impinged for selected species are presented in Table 4-23. As shown in the table, impingement varies considerably from year to year. Because of the seasonal nature of impingement for most species (see Figures 4-4 and 4-5), the annual impingement total is sensitive to the relative magnitudes of flow rate and impingement rate at any point in time. Prior to 1974, only one unit was in operation at Bowline Point, therefore impingement was lower in 1973. No long term trends in numbers of fish impinged are evident.

TABLE 4-22

RELATIVE RANKING OF FISH SPECIES BY NUMBERS IMPINGED AT BOWLINE POINT GENERATING STATION FOR 1973 THROUGH 1976

	1973[a]		1974		1975		1976		1977	
RANK	SPECIES	PERCENT OF TOTAL[b]	SPECIES	PERCENT OF TOTAL[b]	SPECIES	PERCENT OF TOTAL[b]	SPECIES	PERCENT OF TOTAL[b]	SPECIES	PERCENT OF TOTAL[b]
1	White Perch	45.9	White perch	57.2	White perch	64.6	White perch	84.7	White perch	50.3
2	Alewife	13.3	Striped bass	13.2	Rainbow smelt	13.9	Striped bass	6.7	Rainbow smelt	10.8
3	Blueback herring	10.8	Blueback herring	10.1	Striped bass	11.5	Rainbow smelt	3.6	Blueback herring	10.0
4	Atlantic tomcod	7.5	Alewife	5.9	Blueback herring	3.0	Blueback herring	0.9	Gizzard shad	7.3
5	Weakfish	7.2	Atlantic tomcod	3.8	Atlantic tomcod	1.7	Gizzard shad	0.7	Striped bass	6.4
6	Striped bass	4.4	Hogchoker	2.6	Alewife	1.2	Atlantic tomcod	0.5	Alewife	6.0
7	Bay anchovy	2.7	Rainbow smelt	1.9	Gizzard shad	1.0	Alewife	0.5	Atlantic tomcod	4.2
8	Hogchoker	2.1	American shad	1.2	Bluefish	0.8	Tessellated darter	0.4	Hogchoker	1.2
9	Bluefish	1.9	Bluefish	1.0	Hogchoker	0.5	Hogchoker	0.4	Bay anchovy	1.0
10	White catfish	0.7	Bay anchovy	1.0	Bay anchovy	0.4	Bay anchovy	0.3	White catfish	0.5
Ten Most Abundant Species (percent of total)		96.5		97.1		98.5		98.7		97.7

[a] Only one unit operating

[b] Percent by numbers

Source: Orange and Rockland, 1977; Lawler, Matusky, and Skelley, 1978.

Table 4-23

ESTIMATES OF TOTAL IMPINGEMENT AT BOWLINE POINT FOR SELECTED SPECIES OF FISH DURING 1977

	TOTAL FISH IMPINGED					
SPECIES	1973[a]	1974	1975	1976	1977	**AVERAGE**
White Perch	99,659	356,939	391,147	275,670	149,628	254,609±
Striped Bass	8,837	82,205	82,059	25,670	19,072	43,568±
Atlantic Tomcod	12,584	15,612	16,179	4,561	12,778	12,343±
Alewife	19,975	22,323	8,468	5,550	Data Not Available	14,079±
Blueback Herring	18,797	44,969	25,564	5,460	Data Not Available	23,698±
TOTAL	159,852	522,048	523,417	316,911	Data Not Available	380,557

[a] Only unit one operating.

SOURCE: Orange and Rockland, 1977; Lawler, Matusky & Skelly, 1978.

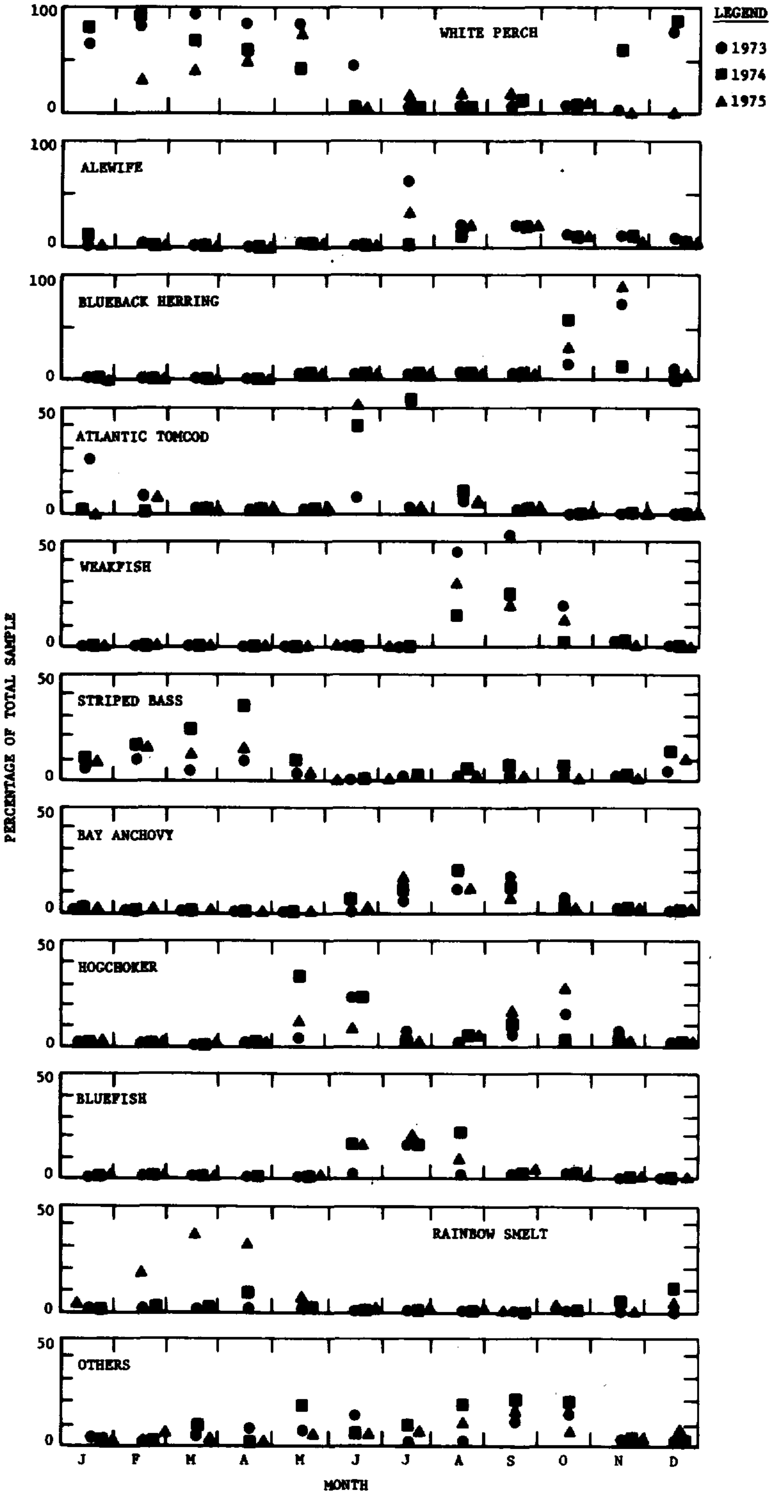
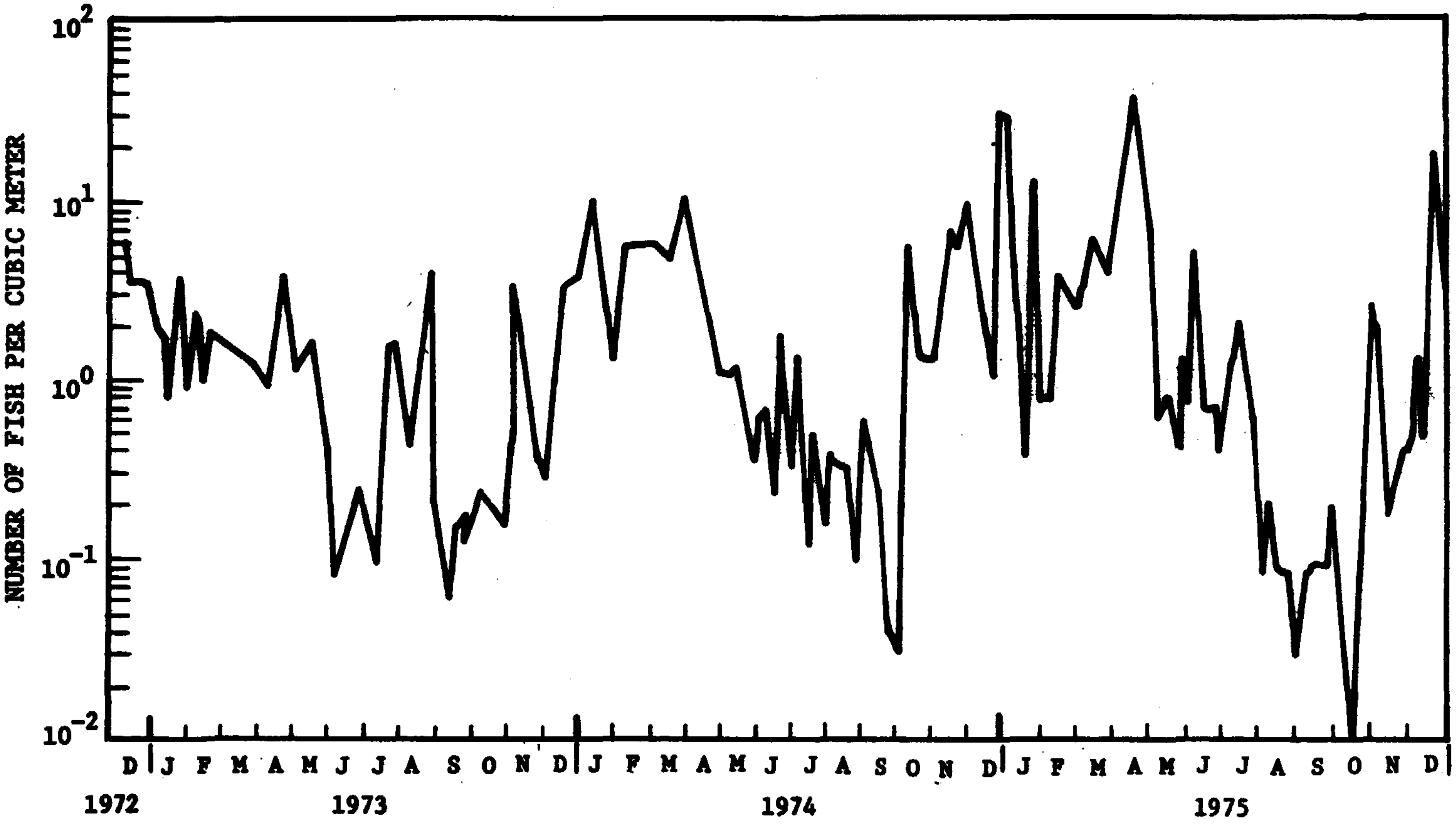


FIGURE 4-4
SEASONAL OCCURRENCE OF VARIOUS SPECIES
IN IMPINGEMENT SAMPLES AT THE BOWLINE GENERATING STATION



Source: Orange and Rockland, 1976.

FIGURE 4-5
SEASONAL VARIATION IN RATE OF FISH IMPINGEMENT
AT THE BOWLINE POINT POWER STATION

4.134 In general, young of the year and yearlings tend to dominate impinged assemblages. Many species show increased impingement rates at night. Impinged fish do not seem to represent the less fit or weaker individuals in a population (Orange and Rockland, 1977). After impingement on the traveling screen and discharge near the intake, the probability for re-impingement of an individual fish has been estimated at 15 to 65 percent, reduced to 10 percent after 24 hours (Orange and Rockland, 1977).

4.135 Impingement survival studies were conducted at the Bowline Point Generating Station in 1974 through 1977 (Orange and Rockland, 1977). Initial and latent (48 to 156 hours) survival were examined to determine the overall effects of the impingement process on affected individuals. Impingement survival at Bowline Point varies with the species of fish and the screenwashing frequency. For example, high initial survival of striped bass (95 percent), white perch (84-97 percent), and Atlantic tomcod (100 percent) was observed during 1976-1977 under continuous screenwash conditions (see Table 4-24). Survival for intermittent screenwash was lower than that for continuous screenwash, and survival of clupeids was lower than that of other species (66 percent for continuous screenwashing; 25 percent for intermittent screenwashing). None of the test clupeids survived the latent holding period. It has been difficult to assess latent impingement mortality because high latent mortality was observed in control organisms (Orange and Rockland, 1977).

4.136 The impact of fish impingement at the Bowline Point Plant can be partially assessed by comparing the number of fish lost through impingement to the number of fish in the source population. The fraction lost through impingement can be calculated by dividing the number impinged by the population standing crop between River Mile 30 and River Mile 50. To provide a conservative estimate of impingement effects, 100 percent mortality among impinged fish has been assumed. Several sampling problems are involved, and a number of assumptions must be made in estimating total numbers of fish impinged and the population standing crop. The procedures that have been followed are summarized by Orange and Rockland (1977) and evaluated in Barnthouse and Van Winkle (1979) and Van Winkle and Barnthouse (1979). Under the assumptions used by Orange and Rockland, the population loss due to impingement of four selected species ranged from 0.001 percent (bay anchovy) to 1.2 percent (white perch) in 1975 and 1976 (see Table 4-25).

4.137 Several factors have been identified that influence impingement estimates at the Bowline Point Plant (Barnthouse, 1979). One of these is the use of flow rates in the extrapolation of weekly or twice-weekly samples to estimates of total impingement. This

TABLE 4-26

IMPINGEMENT SURVIVAL AT BOWLINE POINT FOR SELECTED FISH SPECIES DURING 1976-1977

DATE	SPECIES	NUMBER OF FISH (1976)	PERCENT SURVIVAL INITIAL	PERCENT SURVIVAL 96-HOUR
Jan-Apr(a)	White perch	314	91	23
	Striped bass	45	93	11
Nov-Dec	White perch[a]	5,870	97	55
	White perch[b]	2,620	88	25
	White perch[c]	302	100	23
	White perch[d]	664	92	19
	White perch[e]	1,575	94	9
	White perch[f]	134	--	14
	Atlantic tomcod[a,b]	58	100	100
	Striped bass[a]	418	95	58
	Striped bass[b]	269	92	21
	Striped bass[c]	35	100	20
	Striped bass[d]	32	100	34
	Striped bass[e]	172	96	13
	Clupeid[a]	137	66	0
	Clupeid[b]	50	25	0
		(1977)		
Jan-Feb	White perch[a]	1,946	84	26
	White perch[d]	173	99	25
	White perch[b]	53	74	14

[a] Collection pit samples under continuous screenwash mode.
[b] Collection pit samples under intermittent screenwash mode.
[c] Control samples from impingement collection pit.
[d] Discharge pipe samples under continuous screenwash mode
[e] Discharge pipe samples under intermittent screenwash mode
[f] Cpntrol samples from impingement sluiceway discharge pipe.

Source: Orange and Rockland, 1977.

TABLE 4-25

MONTHS OF GREATEST AND LEAST IMPINGEMENT OF STRIPED BASS AT POWER PLANTS ON THE HUDSON RIVER

	MONTHS OF GREATEST IMPINGEMENT			MONTHS OF LEAST IMPINGEMENT		
POWER PLANT	1973	1974	1975	1973	1974	1975
Bowline Point	1,2,4,12	1-3	1,3,4,12	6,8,-10	6-9	6,8-11
Lovett	4,8,11,12	1,2,4	1-4	1,5,7,10	5,7-9	5,7,8,10
Indian Point 1		1,3,4,12			6-9	
Indian Point 2	1,3,4,12	1-3,5	2-4,7,8	5,7,9,10	6,7,9,10	3,5,6,11
Roseton		5,6,10,11			1-4	
Danskammer 1 and 2	9-12	6-9		1-4	1-3,5	
Danskammer 3 and 4	9-12	6-9		1,3-5	2-4,11	
Albany		6-9			1-3,12	

Source: Barnthouse et al., 1977.

procedure is based on the assumption that impingement is directly proportional to the volume of water entering the plant. Although this assumption may not be totally valid, it is not expected to introduce a systematic error or bias into the results. However, Barnthouse (1979) has identified the following four biases which may potentially affect impingement estimates:

- Collection Efficiency -- Not all impinged fish are actually collected and counted during screenwash monitoring. This causes impingement estimates to be lower than the number of fish actually impinged.

- Reimpingement -- Depending on the relative location of impinged fish return and water intakes, fish may be impinged more than once. This bias would tend to overestimate the occurrence of impingement.

- Impingement on Inoperative Screens -- When a screen is inoperative and cannot be rotated and washed, it continues to impinge fish. A screen that is inoperative for one to five days may impinge about 11 percent as many fish as would a normally operating screen during that period. Such breakdowns occurred "on many occassions from 1974 through 1976" at Bowline (Barnthouse, 1979) and would cause an underestimate of impingement.

- Impingement Survival -- Not all impinged fish are killed. For some species (notably Atlantic tomcod), a substantial proportion of impinged fish appear to survive. The assumption that all impinged fish are killed would tend to inflate estimates of impingement impact.

In an assessment of these biases at the Bowline Point Plant, Barnthouse (1979) concluded that no adjustment factors in excess of 20 percent would be required for existing impingement estimates for clupeids and Morone spp. (Orange and Rockland, 1977), but in the case of Atlantic tomcod the utility consultant appears to have overestimated the impact of impingement during the September to April period by a factor of 1.7.

4.138 Studies to evaluate the effectiveness of using additional barriers at the intakes were initiated at Bowline Point in April 1976. During the studies, stationary nets were placed in front of the intakes and located in a water velocity field where currents were weak enough to allow fish to move along the net or out of the area to avoid impingement. Preliminary baseline studies comparing the two Bowline Point units showed that, under normal operating conditions (no nets), Unit 1 impinged only 29 percent as many white perch and 38 percent as many striped bass as Unit 2 (Table 4-26). However, when the net was installed across the intake of Unit 2, impingement was reduced to the extent that Unit 2 impinged fewer fish than Unit 1. Comparison of 0.95 cm and 1.27 cm nets indicates that the smaller net is more effective at reducing impingement.

4.139 Closed Cycle Cooling in 1981. With the installation of closed cycle cooling at Bowline in 1981, the intake of Hudson River water will be reduced by 98 percent from the 784,000 gpm required for service and once-through cooling water to 16,000 gpm required for make-up and service water. Entrainment of phytoplankton zooplankton; and fish eggs, larvae, and juveniles will be reduced proportionately. Mortality, however, is expected to be 100 percent. The rate of impingment on the traveling screens would probably depend on the velocity conditions existing under the new pumping conditions, but is expected to be very low. The phytoplankton and zooplankton communities in the Hudson River near Bowline are unlikely to be materially affected by the quantity of organisms lost to makeup water.

4.140 Release of blowdown water from each of the cooling towers will be 3300 gpm at a temperature 19°F above ambient. If a diffuser is used for the discharge, measurable effects on the river ecosystem are unlikely. If a surface discharge is used, some localized effect on the aquatic system in the vicinity of the discharge may occur because of the elevated temperature of the effluent. The more sedentary bentic organisms would probably be affected the most.

4.141 It is expected that concentrations of chemicals in the blowdown water will all meet applicable state and Federal standards, and should have no appreciable effect on the receiving waters (see Water Quality section).

Impacts of Roseton Generating Station

4.142 Data available for an analysis of the impacts of Roseton Units 1 and 2 on the Hudson River are primarily for the years 1971 through 1976. Because the units did not begin full power operation until mid to late 1974 (Unit 2 in August and Unit 1 in late December), the data include both the effects of the nearby Danskammer plant (472 MWe, requiring 316,000 gpm cooling flow), which has been operational since 1951, and the Roseton Plant. The following discussion relies on data contained in Quirk, Lawler, and Matusky (1973), Lawler, Matusky, and Skelly (1975b, 1976b), Ecological Analysts (1976b), and Central Hudson Gas and Electric (1977).

4.143 Phytoplankton. Long term studies of the abundance and species composition of phytoplankton communities in the Roseton area

TABLE 4-26
SUMMARY OF IMPINGEMENT BARRIER NET STUDIES AT BOWLINE GENERATING STATION 1976-1977

SPECIES	n[b]	UNIT 1 NET CONFIGURATION	UNIT 1 NUMBER OF FISH IMPINGED	UNIT 2 NET CONFIGURATION	UNIT 2 NUMBER OF FISH IMPINGED	RATIO OF IMPINGEMENT AT UNIT 1 TO IMPINGEMENT AT UNIT 2	t-TEST FOR DIFFERENCE BETWEEN UNIT 1 AND UNIT 2
White Perch	29	No Net	265.38	No Net	915.63	0.29	-2.81**
	37	No Net	922.13	1.27-cm[d]	646.19	1.43	2.15*
	19	0.95-cm[d]	42.15	1.27-cm[d]	110.66	0.38	-5.28**
Striped Bass	22	No Net	21.48	No Net	93.55	0.23	-2.85**
	37	No Net	115.98	1.27-cm[d]	39.69	2.92	2.25*
	11	0.95-cm[d]	4.32	1.27-cm[d]	11.46	0.38	-3.06**

*Significant difference at $\alpha=0.05$

**Significant difference at $\alpha=0.01$

[a] Number of fish per million cubic meters of intake water

[b] Number of paired samples

[c] Two-sided paired t-test

[d] Mesh size of net

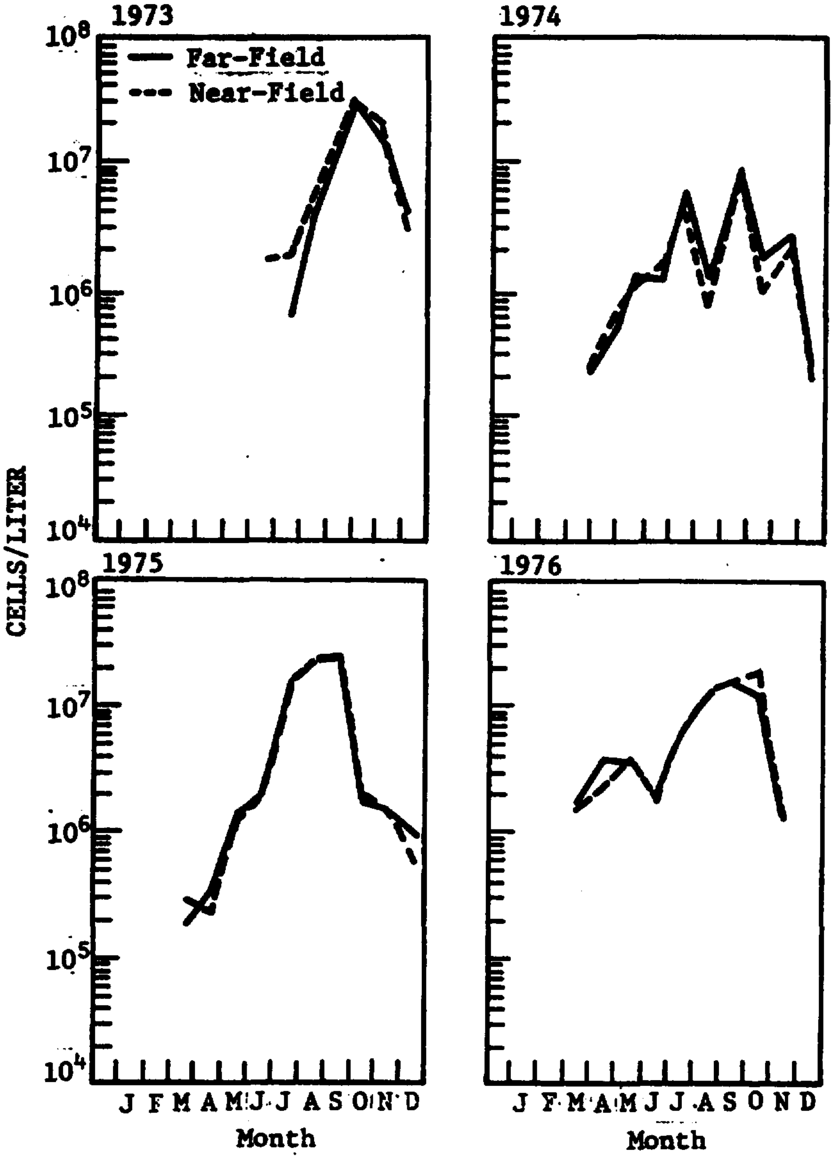
Source: Orange and Rockland, 1978.

have found no spatial distributions that could be related to plant operation (Central Hudson Gas and Electric, 1977). The quantity of phytoplankton entrained varied seasonally, with peak densitites occurring during late spring, summer, and early fall (see Figure 4-6). After entrainment, primary production rates were consistently suppressed when discharge temperatures exceeded 28 C. However, due to rapid dilution of discharge waters, no entrainment effects were detected beyond the plant discharge. Available data indicate that the operation of Roseton Units 1 and 2 should have only a slight effect on the phytoplankton community of the Hudson River in the vicinity of the power plant.

4.144 Zooplankton. Microzooplankton entrainment at Roseton varies seasonally with a spring maximum followed by a decrease during the summer and a second peak in early fall (Central Hudson Gas and Electric, 1977). The observed spatial distributions of microzooplankton around Roseton could not be correlated with entrainment effects of the power plant. Entrainment survival studies during 1975 and 1976 showed that microzooplankton generally sustained initial mortalities averaging 12 to 16 percent after passing through the plant (see Table 4-27 for sample results). Latent mortality after 48 hours averaged 6 to 10 percent. Mortality was independent of discharge temperature up to 35 C. Results from thermal tolerance laboratory studies suggest that substantial entrainment mortality from thermal effects alone should be expected only under full load and/or reduced pump flow conditions. From these lines of evidence, it is concluded that the effects of power plant entrainment on microzooplankton communities in the Roseton area are minimal.

4.145 Studies of macrozooplankton communities in the Roseton area have suggested no effects at the population or community level that could be associated with power plant entrainment. Survival studies have shown that macrozooplankton generally sustain entrainment mortalities averaging less than 10 percent (see Table 4-27 for sample results). Latent mortalities were insignificant at discharge temperatures below about 25 C but appear to have increased with discharge temperatures from 25 to 35 C. Thermal tolerance laboratory investigations using major macrozooplankton species predict that substantial mortality should occur only at temperatures above the range normally observed in the Roseton discharge, therefore little entrainment mortality is expected.

4.146 Benthic Animals. Macrobenthic communities may be affected directly by the discharge of a power plant, or the planktonic larvae of benthic species may be entrained with the power plant cooling water. Migrating benthic adults may periodically occur in the water column and at such times would also be susceptible to entrainment. The overall distribution and abundance of benthic populations in the Roseton area appear to be largely determined by



Source: Central Hudson Gas and Electric, 1977.

FIGURE 4-6
PHYTOPLANKTON ABUNDANCE IN THE ROSETON VICINITY DURING 1973 THROUGH 1976

TABLE 4-27

IMMEDIATE ENTRAINMENT MORTALITY OF ZOOPLANKTON AT THE ROSETON GENERATING STATION*

SPECIES	PERCENT MORTALITY		
	SUMMER	FALL	WINTER
Total microzooplankton	0	10	15
Keratella cochlearis	0	0	0
Coppod nauplii	35	0	0
Eurytemora affinis	0	0	0
Halicyclops fosteri	0	0	17
Bosmina longirostris	0	0	0
Total macrozooplankton	0	0	0
Gammarus daiberi	0	0	0
Chaoborus punctipennis	5	0	0

*Zeros mean that no significant difference was found between immediate mortality in intake and discharge samples.

Source: Ecological Analysts, 1976b.

environmental factors (e.g., sediment type, salinity) that are independent of power plant operation (Central Hudson Gas and Electric, 1977). As a result, nearby benthic communities show considerable seasonal and temporal variation.

4.147 Design features of the Roseton discharge probably minimize its effect on the benthic community in the area of the discharge. Plume studies in 1975, when both units were operating, show that the heated plume rises to the river surface, so that temperature incre~~ases on the bott~~om in the vicinity are only several degrees fahrenheit. This small temperature increase is unlikely to affect benthic communities exposed to it. Some scour may occur in the immediate vicinity of the intake and discharge ports, but the total area affected should be very small in relation to total bottom area in the Roseton vicinity.

See pg 4-91

4.148 Many benthic species, especially dipterans such as Chaoborus sp., have planktonic larvae, which would be subject to entrainment mortality. Entrainment mortality has been found to be low for Chaoborus (see Table 4-27). Mortality of other dipterans has not been directly measured, but river populations are unlikley to be seriously affected. Normal stream drift would replace some larvae lost to entrainment.

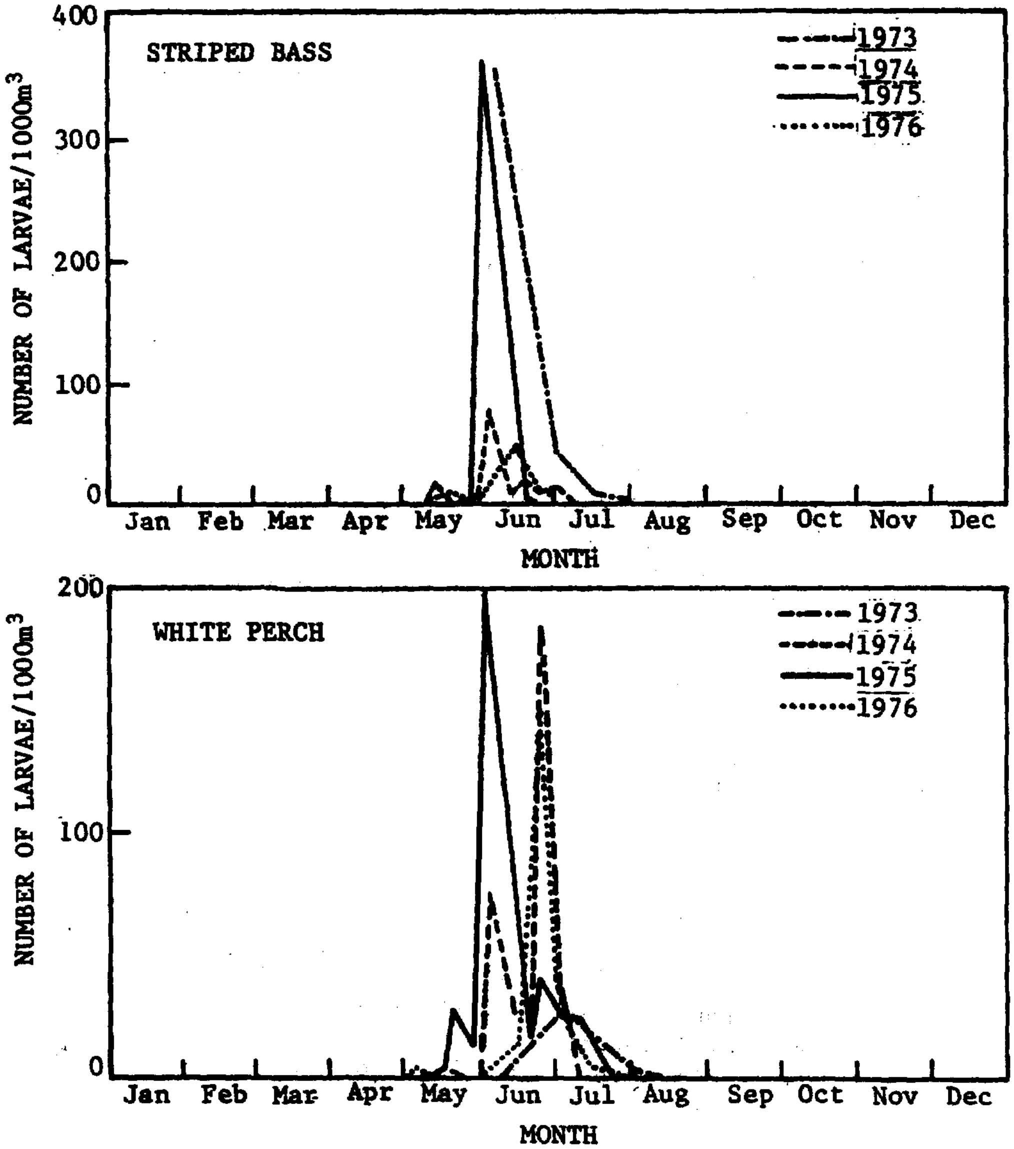
4.149 Entrainment of Fish Eggs, Larvae, and Juveniles. Cooling water for the Roseton Plant is taken directly from the Hudson River at River Mile 66 passed through the plant, and discharged at a location slightly downstream of the intake. Entrainment sampling has been carried out since 1973 using collecting devices at the plant intake and intermittent sampling has been conducted at the discharge to estimate the types and numbers of organisms passing through the plant. Fish eggs, larvae, and juveniles small enough to pass through the traveling intake screen (0.95 cm or 3/8 in) are entrained with the cooling water passing through the condenser and then are discharged back into the river. The primary factors that may cause adverse effects during entrainment are mechanical and thermal shock. The quantity of organisms entrained changes with seasonal variation in the abundances of fish eggs and larvae in surrounding waters, and with seasonal changes in flow rates of cooling water in the power plant.

4.150 In addition to the quantity of organisms entrained, the rates of immediate and latent entrainment mortality have been studied. Sublethal effects of passage through the power plant may also be important but are not well known. Because plant conditions vary depending on operational load, season, and equipment used, entrainment mortality varies with time. To assess the long range effect of entrainment by power plants, the loss due to entrainment must be compared to species standing stocks.

4.151 It is difficult to measure accurately the concentrations of eggs, larvae, and juveniles entrained by a power plant. Roseton data available to date are results from analysis of samples taken using 0.580 mm plankton nets (Central Hudson Gas and Electric, 1977). When nets are used to sample entrained organisms, the major sampling problems include net avoidance, clogging of nets, extrusion of eggs and larvae, and inaccurate measurement of water volume sampled. In an assessment of ichthyoplankton sampling programs used at Hudson River power plants, Carpenter (undated) concluded that Roseton sampling methods would tend to underestimate entrainment of fish eggs, larvae, and juveniles. The magnitude of the bias was not estimated.

4.152 Prevalent species collected at the Roseton Plant intake included white perch, striped bass, Atlantic Tomcod, Alosa spp. (probably alewife and blueback herring), and the bay anchovy. Alosa spp. eggs and larvae were entrained in greatest numbers. White perch eggs are demersal and adhesive and are generally not susceptible to entrainment (Figure 4-7). No white perch eggs were collected in 1974, those eggs collected in 1975 and 1976 were taken in greater numbers in bottom samples. Concentrations of white perch larvae fluctuated during 1974-1976, but peaked during May and June. The eggs of the striped bass were typically found on only a few collecting dates per year. The data suggest that late May and early June is the period of peak striped bass egg abundance at the Roseton intake. The abundance of striped bass juveniles was greatest during June. Atlantic tomcod eggs, although demersal and adhesive, have been collected in small number at Roseton during January through March. Maximum abundance of tomcod larvae was observed during March. Alosa spp. eggs and larvae were entrained in larger numbers than other species, occuring from April through July. No bay anchovy eggs were collected at Roseton during the sampling period. Bay anchovy larvae were collected from mid-July through mid-September. In addition, American eel, rainbow smelt, sunfishes, tesselated darter, white sucker, yellow perch, and various minnows and carps have occurred in entrainment samples at Roseton.

4.153 Entrainment mortality at the Roseton Plant has been estimated through comparison of survival rates in fish collected at the plant intake and discharge. Intake survival was used as a control because organisms collected at the intake were not entrained but were subjected to sampling and handling stress. The initial entrainment survival percentages (proportion surviving at intake divided by proportion surviving at discharge times 100) for selected entrained fish species in 1976 are presented in Table 4-28. Initial entrainment mortality for striped bass, white perch, and clupeids was generally 60 percent or greater for discharge temperatures below 30 C. At higher discharge temperatures, entrainment survival is



Source: Central Hudson Gas and Electric, 1977.

FIGURE 4-7
MEAN ABUNDANCE OF STRIPED BASS AND WHITE PERCH LARVAE AT THE ROSETON GENERATING STATION DURING 1973 THROUGH 1976

TABLE 4-28

ENTRAINMENT SURVIVAL OF ICHTHYOPLANKTON AT THE ROSETON PLANT DURING 1976

SPECIES	YOLK-SAC LARVAE TEMPERATURE (C)	YOLK-SAC LARVAE PERCENT SURVIVAL	POST-YOLK SAC LARVAE TEMPERATURE (C)	POST-YOLK SAC LARVAE PERCENT SURVIVAL	JUVENILES TEMPERATURE (C)	JUVENILES PERCENT SURVIVAL
Striped bass	24.0-29.9	--	24.0-29.9	62	24.0-29.9	--
	30.0-32.9	--	30.0-32.9	55	30.0-32.9	--
	33.0-37.9	--	33.0-37.9	8	33.0-37.9	55
White perch	24.0-29.9	--	24.0-29.9	83(NS)	24.0-30.5	--
	30.0-32.9	--	30.0-32.9	38	30.6-33.5	51
	33.0-37.9	--	33.0-37.9	6	33.6-37.0	36
Clupeids	24.0-30.5	--	24.0-30.5	59	24.0-30.5	--
	30.6-33.5	--	30.6-33.5	14	30.6-33.5	16
	33.6-37.0	--	33.6-37.0	0	33.6-37.0	0

Note: Dashes indicate sample size at intake or discharge was less than 7. NS indicates survival at the discharge not significantly lower than that at the intake for a one-tailed t-test at the $\alpha = 0.05$ level.

Source: Central Hudson Gas and Electric, 1977.

generally low (0-55 percent). In most species studied, entrainment mortality appears to be related primarily to thermal stress. (Ecological Analysts, 1978b; Central Hudson Gas and Electric, 1977.) As found at the Bowline Point Plant, latent survival is expected to be somewhat less than initial survival, but was not measured at Roseton.

4.154 Central Hudson Gas and Electric (1977) has calculated estimates of entrainment-related loss of fish eggs, juveniles, and larvae based on species standing crops, rates of entrainment, and survival rates. These estimates are expressed as the number of larvae killed by entrainment in a given year divided by the standing crop of the larvae between River Mile 50 and River Mile 70. Losses for the following species have been estimated:

	PERCENT LOSS OF STANDING CROP FROM ENTRAINMENT[a]		
SPECIES	1974	1975	SOURCE
White Perch	0.49	1.75	Central Hudson Gas and Electric (1977)
Striped Bass	--	3.5	McFadden (1977)
Alosa spp.	0.54	1.10	Central Hudson Gas and Electric (1977)

[a] standing crop between River Mile 50 and River Mile 70.

Quantitative estimates have not been made for other species affected, such as the bay anchovy and Atlantic tomcod.

4.155 Fish Impingement. Eight traveling screens are utilized at the Roseton Generating Station cooling water intake to prevent fish from entering the plant. The traveling screens are constructed of 0.95 cm (3/8 inch) mesh and are cleared of trapped fish and debris with a spray of water. A disposal trough returns screen washings to the Hudson River. When impingement sampling is carried out, fish retained on the screen are sorted from the debris and collected for study. A weekly sampling program was initiated in July 1973 and data are now available from samples taken through 1976.

4.156 A total of 41 species were collected from the Roseton intake screens between July 1973 and December 1976. Based on four years of data presented in Table 4-29, white perch (43-71 percent) and blueback herring (5-37 percent) were most numerous among the impinged assemblage. Spottail shiner, Atlantic tomcod, alewife, bay anchovy and white catfish each represented 2 to 5 percent of the individuals when averaged over the three year period. Striped bass

TABLE 4-29

TOTAL ABUNDANCE AND PERCENT COMPOSITION OF ALL FISH SPECIES IN IMPINGEMENT COLLECTIONS FROM THE ROSETON GENERATING STATION FROM 1973 THROUGH 1976

COMMON NAME	YEAR 1973 NUMBER	PERCENT OF TOTAL	1974 NUMBER	PERCENT OF TOTAL	1975 NUMBER	PERCENT OF TOTAL	1976 NUMBER	PERCENT OF TOTAL	MEAN PERCENT OF TOTAL FOR 1973 THROUGH 1976
White perch	8798	42.75	5654	61.77	18411	49.10	15136	71.10	56.20
Blueback herring	7676	37.30	485	5.30	9549	25.47	1404	6.60	18.66
Spotail shiner	334	1.62	700	7.65	1902	5.07	1107	5.20	4.88
Atlantic tomcod	78	0.38	860	9.40	613	1.63	1116	5.29	4.18
Alewife	1435	6.97	254	2.78	1967	5.25	329	1.55	4.13
Bay anchovy	1248	6.06	515	5.62	408	1.09	333	1.56	3.58
White catfish	190	0.92	234	2.56	1059	2.82	406	1.91	2.06
Striped bass	416	2.02	86	0.94	207	0.55	89	0.42	0.98
Gizzard shad	15	0.07	25	0.27	736	1.96	333	1.56	0.96
Bluegill	118	0.57	20	0.22	729	1.94	53	0.25	0.74
Pumpkinseed	16	0.08	77	0.84	267	0.71	273	1.28	0.72
Rainbow smelt	97	0.47	14	0.15	445	1.19	74	0.35	0.54
Hogehoker	74	0.36	40	0.44	243	0.65	129	0.61	0.52
American shad	19	0.09	28	0.31	342	0.91	51	0.24	0.39
Tessellated darter	6	0.03	19	0.21	101	0.27	153	0.72	0.31
American eel	5	0.02	27	0.29	134	0.36	85	0.40	0.27
Golden shiner	29	0.14	38	0.41	57	0.15	35	0.16	0.22
Goldfish	12	0.06	23	0.25	51	0.14	47	0.22	0.17
Brown bullhead	3	0.01	16	0.17	35	0.09	32	0.15	0.11
Yellow perch	-	-	11	0.12	52	0.14	31	0.15	0.10
Bluefish	-	-	1	0.01	109	0.29	-	-	0.08
Banded killifish	3	0.01	6	0.07	31	0.08	34	0.16	0.08
Largemouth bass	-	-	2	0.02	14	0.04	6	*	0.02
Atlantic sturgeon	3	0.01	4	0.04	9	0.02	2	*	0.02
Redbreast sunfish	-	-	4	0.04	6	0.02	4	*	0.01
Black crapple	3	0.01	2	0.02	-	-	3	*	<0.01
White crapple	-	-	-	-	-	-	-	-	<0.01
Shortnose sturgeon	-	-	1	0.01	-	-	-	-	<0.01
Central mudminnow	-	-	-	-	-	-	1	*	<0.01
Carp	-	-	-	-	4	0.01	-	-	<0.01
Emerald shiner	-	-	-	-	-	-	1	*	<0.01
Spotfin shiner	-	-	-	-	1	*	-	-	<0.01
White sucker	-	-	2	0.02	-	-	-	-	<0.01
Yellow bullhead	-	-	-	-	3	*	-	-	<0.01
Mummichog	-	-	-	-	-	-	1	*	<0.01
Fourspine stickleback	-	-	-	-	-	-	1	*	<0.01
Threespine stickleback	-	-	2	0.02	4	0.01	1	*	<0.01
White bass	-	-	-	-	1	*	4	*	<0.01
Rock bass	1	*	-	-	3	*	2	*	<0.01
Warmouth	-	-	-	-	1	*	-	-	<0.01
Spot	-	-	-	-	-	-	2	*	<0.01
TOTAL NUMBER COLLECTED	20579	99.9	9153	99.9	37495	99.9	21288	99.8	
TOTAL NUMBER OF SPECIES	23		30		33		33		

- None Collected
* Less than 0.01 percent

Source: Central Hudson Gas and Electric, 1977.

accounted for less than 1 percent of the individuals during the same period. Because of the seasonal nature of impingement rates (see Figure 4-.8), for most species the annual total number of fish impinged is sensitive to the relative magnitudes of the flow rate and the impingement rate at a given time. No long-term trends in numbers of fish impinged are evident and yearly changes in impingement probably reflect natural fluctuations in populations of fish species.

4.157 In general, young of the year and yearlings tend to dominate impinged assemblages. Many species show increased impingement rates at night. Impinged fish do not seem to represent the less fit or weaker individuals.

4.158 After impingement of white perch on the traveling screen and discharge of the fish into the Hudson River, the probability of re-impingement was highest at mid-flood tide (37 percent) and lowest at mid-ebb (1.7 percent). Nearly all re-impinged fish were captured within 1.5 hours of release. The combined re-impingement rate for live white perch released over all tidal stages was 23 percent.

4.159 Impingement survival studies were conducted at the Roseton Generating Plant during 1975 and 1976. Initial and latent survival (after 96 hours) were examined to determine the overall effects of the impingement process on affected individuals. Impingement survival at Roseton varies with the species of fish and the screenwashing frequency. Sample data presented in Table 4-30 demonstrate the relatively high initial survival and substantially lower 96 hour survival observed for white perch and striped bass. Blueback herring, alewife, centrarchids, and tomcod appeared more sensitive to impingement than <u>Morone</u> spp. Continuous screenwashing resulted in higher survival than intermittent wash.

4.160 The impact of fish impingement at the Roseton Plant can be partially assessed by comparing the number of fish lost through impingement to the number of fish in the source population. The fraction lost through impingement can be calculated by dividing the impingement loss value by the size of the population standing crop between River Mile 50 and River Mile 70. To provide conservative estimates of impingement effects, 100 percent mortality of impinged fish is assumed. Several sampling problems are involved, and a number of assumptions must be made in estimating total numbers of fish impinged and the population standing crop. The procedures that have been followed in making these estimates are summarized by Barnthouse and Van Winkle (1979) and Van Winkle and Barnthouse (1979). Under the assumption used in Central Hudson Gas and Electric (1977), the population loss due to Roseton impingement of four selected species ranged from 0.001 percent (bay anchovy) to 0.5 percent (white perch) in 1975 and 1976 (see Table 4-31).

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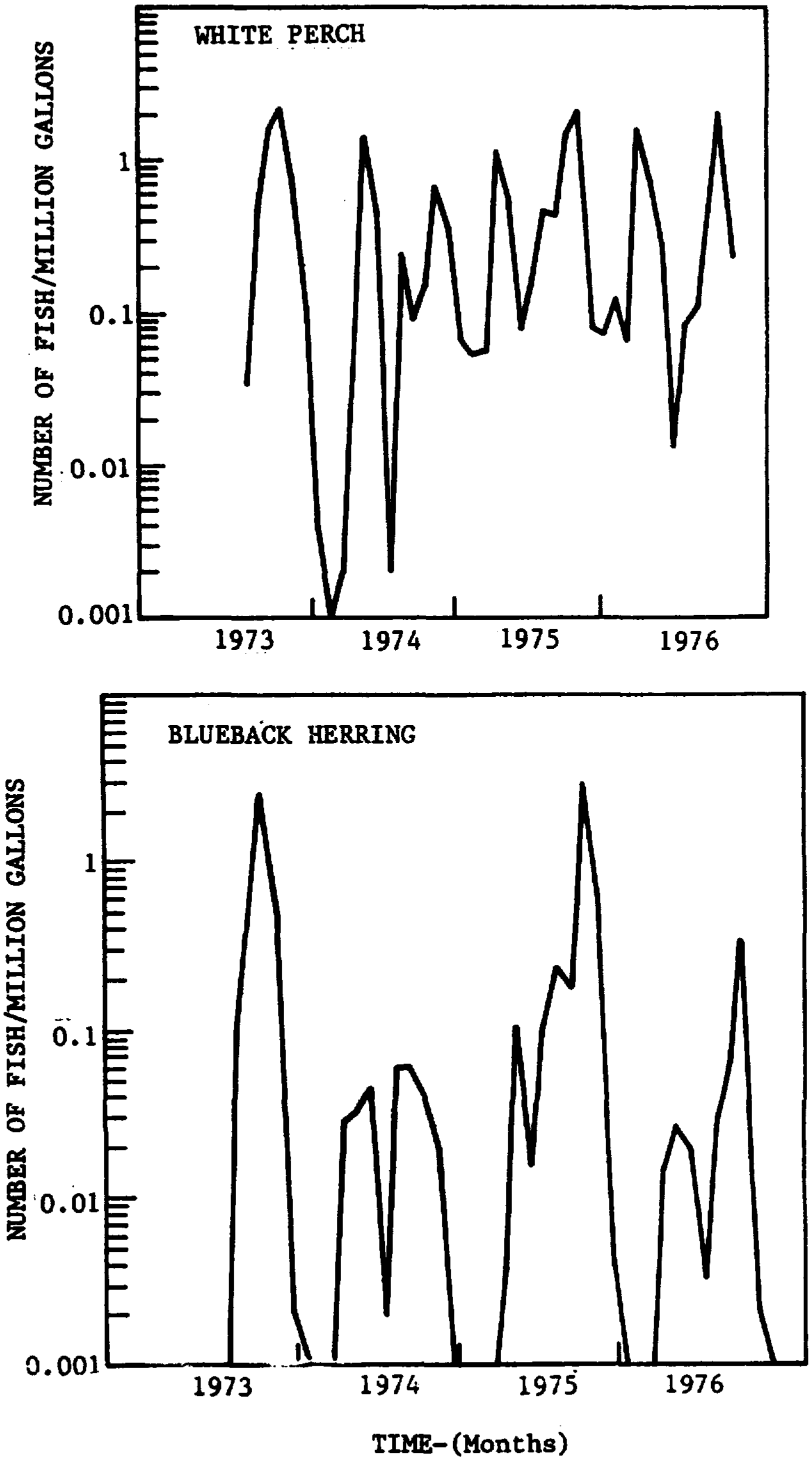

Source: Central Hudson Gas and Electric, 1977.

FIGURE 4-8
SEASONAL VARIATION IN RATES OF IMPINGEMENT AT THE ROSETON GENERATING STATION FOR WHITE PERCH AND BLUEBACK HERRING

TABLE 4-30

SUMMARY OF FISH IMPINGEMENT SURVIVAL AT THE ROSETON GENERATING STATION DURING THE FALL OF 1975[a]

SPECIES	NUMBER OF FISH	PROPORTION ALIVE INITIALLY	PROPORTION ALIVE AFTER 96 HOURS
	CONTINUOUS WASH[b]		
White perch	201	0.83	0.08
Striped bass	4	0.50	0.25
Blueback herring	16	0.25	0.00
Alewife	8	0.25	0.00
Centrarchids	0	--	--
Atlantic tomcod	4	0.25	0.00
	2-HOUR WASH[b]		
White perch	667	0.60	0.01
Striped bass	11	0.56	0.00
Blueback herring	5,833	0.06	0.00
Alewife	162	0.16	0.00
Centrarchids	25	0.40	0.12
Atlantic tomcod	13	0.39	0.08
	4-HOUR WASH[b]		
White perch	239	0.22	0.00
Striped bass	5	0.00	0.00
Blueback herring	327	0.03	0.00
Alewife	54	0.00	0.00
Centrarchids	5	0.60	0.00
Atlantic tomcod	2	0.00	0.00
	6-HOUR WASH[b]		
White perch	684	0.25	0.00
Striped bass	6	0.00	0.00
Blueback herring	4,476	0.06	0.00
Alewife	169	0.06	0.00
Centrarchids	0	--	--
Atlantic tomcod	0	--	--

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[a] Control fish collected from the Hudson River with beach seines. Only striped bass and white perch were maintained. Survival was generally at or near 100 percent for the 96-hour holding period.

[b] Washwater pressure was 96 psi.

Source: Central Hudson Gas & Electric (1977)

TABLE 4-31

ESTIMATIONS OF STANDING CROP LOSS THROUGH ROSETON IMPINGEMENT DURING 1975-1976[a]

SPECIES	PERCENT[b] OF STANDING CROP LOST THROUGH ROSETON IMPINGEMENT 1975	1976
White Perch	0.2 - 0.3	0.3 - 0.5
Blueback Herring	0.12 - 0.36	0.07 - 0.20
Atlantic Tomcod	0.01 - 0.02	0.03 - 0.05
Bay Anchovy	0.001 - 0.001	0.02 - 0.03

[a] Standing crop between River Mile 50 and River Mile 70.

[b] Range shown is for 30% and 50% sampling gear efficiency.

Source: Central Hudson Gas and Electric, 1977.

4.161 Several factors have been identified that may bias impingement estimates at Hudson River Power Plants (Barnthouse, 1979). These biases have been discussed in the section on impingement at the Bowline Point Power Station. In an assessment of impingement estimate bias at the Roseton Plant, Barnthouse concluded that the following adjustment factors should be applied to Roseton impingement estimates presented in Central Hudson Gas and Electric (1977).

- Estimate of clupeid impingement should be increased by a factor of 1.4.
- Estimates of Atlantic tomcod impingment from September to April should be reduced by a factor of 0.6.
- Estimates of white perch and striped bass impingement were not found to be biased in excess of 20 percent, the acceptable error limit used by Barnthouse.

Cumulative Impacts of Present Generating Stations on the Hudson River Ecosystem

4.162 The overall effect of the simultaneous operation of the Bowline Point, Lovett, Indian Point, Roseton, and Danskammerpower generating stations on the ecosystem of the Hudson River estuary downstream of the dam at Troy are discussed in this section. The effects of the recently constructed Bowline Point, Indian Point, and Roseton plants, are considered in more detail because the other older plants have been in operation long enough so that their effects may already be reflected in the available baseline data.

Phytoplankton

4.163 Several years of sampling in the vicinity of the Bowline Point, Lovett, Indian Point, Roseton, and Danskammer power plants has revealed no significant local changes in the phytoplankton community attributable to the operation of these generating stations. However, these data were not obtained under full-power conditions for all proposed power plants along the entire river. Model estimates of the temperature distribution along the river for April through September under full power conditions and once-through cooling for the Albany, Roseton, Danskammer, Indian Point, Lovett, Bowline Point, and 59th Street power stations indicate that an overall temperature increase of about 1 to 3 F will occur for a few miles downstream from the Bowline generating station (Appendix E). The average temperature increase is variable with distance from a discharge source and is highest in the Indian Point-Bowline Point region.

4.164 The effects on the phytoplankton community of a year-round increase in temperature of only a few degrees is difficult to predict. If any alteration occurs it is likely to be most prevalent during the seasonal extremes of temperature. During a mild winter, the switch to diatom dominance may not be as prominant. During the warmest summer months, an additional heat load would favor blue-green algae, a pattern that already naturally occurs in the estuary (see Figure 2-18). Some changes in species composition are possible. Alterations, if any, are most likely to occur in the Bowline Point-Indian Point region, where water temperature will be increased the most. Ecological Analysts (1977b) have investigated the cumulative effects of Roseton, Indian Point, and Bowline Point generating stations on Hudson River phytoplankton. In this study, it is concluded that no adverse effects of entrainment on phytoplankton communities have been detected or are predicted. Peak discharge temperatures may result in slight reductions (10-20 percent) in algal productivity at some sites. However, no reductions should be detectable beyond the immediate vicinity of the power plant discharges.

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Microzooplankton

4.165 Studies of entrainment mortality of microzooplankton have produced mixed results. At Bowline Point and Indian Point, mortality increased during the summer, especially for copepods. At Roseton, copepod nauplii experienced a significant mortality during the summer.

4.166 Effects of entrainment mortality on the overall river population depend on the total number of microzooplankton lost from the river and the ability of the population to replace those lost. Sampling programs at Bowline Point, Lovett, Indian Point, and Danskammer have found no changes in the zooplankton communities of these areas attributable to power plant operation. An investigation performed by Ecological Analysts (1977b) concluded that no adverse impacts on Hudson River microzooplankton communities have been detected or are predicted to result from entrainment at Bowline Point, Roseton, and Indian Point generating stations. The combination of modest entrainment mortality and rapid regeneration times typical of microzooplankton species makes it unlikely that this community will be significantly influenced directly by entrainment.

4.167 As with phytoplankton, the effect of a small year-round increase in average water temperature on microzooplankton is difficult to predict. Some species composition changes are possible during years of exceptionally warm ambient water temperatures. Species changes could also take place if phytoplankton species composition is altered by warmer temperatures. Alterations, if any, are most likely to occur in the Bowline Point-Indian Point region, where water temperature will be raised the most.

Macrozooplankton

4.168 With the exception of Neomysis americana (oppossum shrimp), measured entrainment mortality of the major macrozooplankton species is very low. Neomysis, a saltwater species, is susceptible to entrainment only by Bowline Point, Lovett and Indian Point when saline water is in their vicinity during late summer and fall. Neomysis is usually abundant only when salinity is one part per thousand or greater.

4.169 Apparently, entrainment mortality of Neomysis is only a problem at Indian Point when river temperatures are warmest. Limited data at Bowline Point show that Neomysis was entrained in small numbers and experienced no detectable mortality. The additional mortality within the river population of Neomysis represented by entrainment losses at Indian Point has not been calculated, but are likely to be small. An investigation performed by Ecological Analysts (1977b) concluded that the operations of once-through cooling systems at Bowline Point, Indian Point, and Roseton generating stations would have no adverse effects on the macrozooplankton communities of the Hudson River, nor on the organisms that feed on these communities. It is unlikely that operation of the power plants on the estuary will significantly affect the macrozooplankton community.

Benthic Animals

4.170 The use of bottom diffusers at Bowline and Roseton and the arrangements for maintaining the plume on the surface at Indian Point reduce the direct impact of the thermal discharges on the benthic community in the estuary. No widespread modifications of the benthos attributable to the operation of the power plants have been found in several years of field sampling in the vicinity of these plants (Ecological Analysts 1977b). Some local effects of scouring at the intake and discharge structures are possible.

4.171 No overall quantitative estimates are available on the entrainment mortality of planktonic stages of benthic organisms. Limited data on Chaoborus punctipennis at Roseton suggest very low mortality for larvae of this dipteran species. Some mortality can be expected for other species as well. The effect of this entrainment mortality on the benthic community is unknown at this time, but is likely to be quite small.

4.172 The overall increase in average water temperature that may occur because of the interaction of discharge plumes along the river, especially in the Bowline Point-Indian Point region (Barnthouse et al., 1977; Appendix E) may have only a small effect, if any, on the benthic community. The general tendency for the warmest water to remain near the surface will prevent benthic animals from experiencing the main impact of the thermal effluents. By the time mixing of the heat load into deeper water layers has taken place, heat losses to the atmosphere and cooling by dilution with ambient water probably will have reduced the average temperature increase experienced by the bottom animals to 1 F or less.

inconsistent with discharge from Roseton hugging the bottom only [illegible] layers. see pg 4-78

Entrainment of Fish Eggs, Larvae, and Juveniles

4.173 An initial step in predicting how entrainment mortality will affect a fish population in the long term is to estimate the conditional entrainment mortality imposed by power plants. Conditional entrainment mortality is defined as the percentage of eggs and larvae spawned that year that would have been killed if the only cause of death was entrainment resulting from operation of the power plants. Conditional entrainment mortality may be estimated by using measures of entrainment survival, numbers of organisms entrained, and the number of organisms in the pool population. None of these parameters has been measured directly with a high degree of accuracy. Therefore, it is necessary to make assumptions and perform extrapolations to transform available data into estimates of the required parameters. Several approaches have been used to achieve this end. Utilities and their consultants have used a hydrodynamic transport model, which infers entrainment abundances from ratios of plant to river abundances of entrainable organisms (Lawler and McFadden, 1977). In addition, the Utilities have used a simpler approach, in which the number of organisms entrained (estimated from plant samples and flow rate measurements) is divided by the average standing crop of entrainable organisms during the specific time period (estimated from river sampling) (Orange and Rockland, 1977; Central Hudson Gas and Electric, 1977).

4.174 The major sources of bias and inaccuracy in these approaches include grouping entrainable organisms across all entrainable life stages and assumptions about the relative sampling efficiencies of plant and river sampling techniques. A discussion summarizing the limitations of these approaches is provided in Boreman et al. (1979). The Empirical Transport Model (ETM) has been selected by the U.S. Environmental Protection Agency and their consultants to remedy some of these problems in an attempt to approximate conditional entrainment mortality more closely (Boreman et al., 1978).

4.175 Estimates of conditional entrainment mortality are presented in Table 4-32. Several ETM runs were made for each fish population. Runs using conditions existing in 1974 and 1975 are presented to compare ETM estimates to those made by Utilities. Runs using projected cooling water requirements provide a basis for determining the probable impact of Hudson River power plants with expected once-through and closed-cycle operating conditions. Runs using expected future requirements are necessary because additional units have become operational since 1974-1975 (e.g., Roseton, Indian Point Unit 3), and other units are expected to be phased out over the next few years (e.g., units at Lovett, Danskammer, and Indian Point).

4.176 Estimates of conditional entrainment mortality by the U.S. Environmental Protection Agency (Table 4-32) are somewhat greater than but generally similar to estimates of the Utilities for the impacts of Roseton, Indian Point 3, and Bowline Point in 1974 and 1975, the only case for which comparable estimates have been made. The largest impact is predicted for bay anchovy because this species has very poor survival after passing through power plant cooling systems. Conditional mortality predicted for striped bass, white perch, and <u>Alosa</u> spp. due to the operation of all power plants was estimated to be in the range of 10 to 20 percent for 1974 and 1975.

4.177 Projections of the magnitude of conditional entrainment mortality that could prevail under conditions of once-through cooling in the future have been made only by the U.S. Environmental Protection Agency (Table 4-32). In general, conditional entrainment mortality would increase on the order of 3 percent over 1975 estimates for striped bass and white perch and about 10 percent for American shad. Mortality would still be in the range of 15 to 22 percent. Conditional entrainment mortality for bay anchovy, Atlantic tomcod, and <u>Alosa</u> spp. would not change greatly. Mortality to bay anchovy could be very great, although the range of estimates is also large.

4.178 The contribution of each power plant to total conditional mortality with once-through cooling is difficult to estimate because such a breakdown is not given in published reports or hearing testimony. However, a rough estimate based on data contained in McFadden and Lawler (1977, Table) and Table 4-32 suggests that for striped bass and white perch the breakdown could be on the order of the following:

TABLE 4-32

ESTIMATES OF CONDITIONAL ENTRAINMENT MORTALITY RESULTING FROM POWER PLANTS ON THE HUDSON RIVER (percent)

	ESTIMATES OF PAST IMPACTS				EPA PROJECTIONS OF FUTURE YEARLY IMPACTS[b]	
	1974		1975			
SPECIES	EPA[b]	UTILITIES	EPA[b]	UTILITIES	ONCE-THROUGH COOLING[c]	CLOSED-CYCLE COOLING[d]
	ALL POWER PLANTS[e]				ALL POWER PLANTS[e]	
Striped bass	11-15	NE	18	NE	16-22	4-8
White perch	11-12	NE	13	NE	16-17	3-4
Alosa spp.	4	NE	6-11	NE	6-11	1-4
American shad	14	NE	NE	NE	21	4
Atlantic tomcod	NE	NE	5-8	NE	7-8	2
Bay anchovy	54-78	NE	35-46	NE	44-79	13-25
	ROSETON[g], INDIAN POINT 2, AND BOWLINE POINT ONLY[f]				ROSETON, INDIAN POINT 2 AND 3, AND BOWLING POINT ONLY[f]	
Striped bass	7-8	8	13	12	14-17	2-2
White perch	7-8	6	9-10	6	13-15	1
Alosa spp.	2	NE	4-6	NE	5-8	<1
American shad	9	2	NE	NE	18	1
Atlantic tomcod	NE	NE	4-7	4	6-8	2
Bay anchovy	36-65	NE	26-37	NE	38-75	2-8

NE = no estimate made.

[a] Mortality that would result if only factor causing death was power plant operation.

[b] Estimated using the Empirical Transport Model.

[c] Once-through cooling at all power plants.

[d] Closed-cycle cooling at Roseton, Indian Point, and Bowline. Lovett and Danskammer with once-through cooling.

[e] Total mortality resulting from operation of all power plants.

[f] Mortality resulting from operation of these plants only. Difference between e and f is mortality resulting from operation of Danskammer and Lovett.

[g] Unit 2 operational in September 1974, Unit 1 operational in December 1974.

Power Plant	Percent Contribution to Total Entrainment Conditional Mortality	
	Striped Bass	White Perch
Bowline	14	12
Indian Point 2 and 3	43	59
Roseton	19	12
Danskammer and Lovett	24	18

If these estimates are approximately correct, then the operation of the Indian Point station accounts for about one-half of the total impact of entrainment of all power plants. The Bowline Point and Roseton stations each account for only about 10 to 20 percent of total conditional mortality.

4.179 Should closed-cycle cooling be installed at Bowline Point, Indian Point, and Roseton, the conditional mortality due to operation of all power plants would drop to a low level (Table 4-32). One-half or more of the remaining impact would occur at the Lovett, Danskammer, and Albany facilities, which are exempt from any requirement for modification of their cooling systems.

Impingement of Fish

4.180 During the years 1973 through 1977, it is estimated that a total of 1.4 to 3.6 million white perch, striped bass, American shad, alewife, blueback herring, bay anchovy, and Atlantic tomcod were impinged annually at Bowline Point, Roseton, Indian Point, Danskammer, and Lovett Generating Stations (see Table 4-33 and McFadden, 1978). Only the data for 1977 and 1977 in Table 4-33 represent conditions of full-scale commercial operation of all units that will continue to be on-line for the near future (Roseton, Bowline Point, Indian Point Units 2 and 3, Lovell, Danskammer and Albany.) With the exception of striped bass and alewifes, the greatest number of fish are impinged at Indian Point. Impingement of alewifes is spread fairly evenly among all plants except Lovett. Bowline Point and Indian Point account for most of the impingement of striped bass.

4.181 Although the greatest number of fish were impinged in 1977, there is no clear trend of increasing impingement through the years. The 1977 maximum is related to increased impingement of all species at Indian Point during that year. The increase at Indian Point was due to a greater volume of water passing through the plant combined with a higher rate of impingement (No./water volume, i.e., more fish in the water). With the continued full scale operation of the Indian Point Generating Station, it may be expected that this

SPECIES AT HUDSON RIVER POWER
PLANTS DURING 1973 THROUGH 1977

POWER PLANT	TOTAL INDIVIDUALS IMPINGED[a]						
	1973	1974	1975	1976	PERCENT OF TOTAL	1977	PERCENT OF TOTAL
WHITE PERCH							
Bowline[b]	99,700	357,500	368,300	275,700	28	149,600	9
Indian Point[c]	83,900	367,800	299,300	440,600	45	1,094,600	68
Lovett	61,100	87,300	82,800	46,100	5	81,000	5
Roseton	9,100[d]	37,300	139,400	104,200	11	132,000	8
Danskammer	110,550	84,300	98,200	117,700	12	140,800	9
TOTAL	364,300	934,200	988,000	984,300		1,598,000	
STRIPED BASS							
Bowline[b]	9,300	87,600	81,400	25,700	73	19,100	35
Indian Point[c]	1,800	6,300	6,000	6,100	17	27,700	51
Lovett	5,500	9,700	5,300	1,600	5	2,700	5
Roseton	500[d]	600	1,400	600	2	2,700	5
Danskammer	19,000	6,300	2,600	1,400	4	1,900	4
TOTAL	36,100	110,500	96,700	35,400		54,100	
AMERICAN SHAD							
Bowline[b]	200	4,800	1,200	1,200	15	1,400	7
Indian Point[c]	19	1,500	1,100	4,200	54	12,700	66
Lovett	400	1,000	500	45	<1	100	<1
Roseton	21[d]	300	2,300	400	5	2,400	13
Danskammer	1,300	2,400	2,500	2,000	26	2,600	14
TOTAL	1,900[d]	10,000	7,600	7,800[d]		19,200	
ALEWIFE							
Bowline[b]	20,500	22,100	8,400	5,500	25	35,900	23
Indian Point[c]	1,200	6,400	4,200	3,500	16	58,600	37
Lovett	8,700	3,500	4,900	600	3	1,900	1
Roseton	1,900[d]	1,500	12,200	2,400	11	37,300	24
Danskammer	148,900	31,400	29,800	9,900	45	24,600	16
TOTAL	181,200	64,900	59,500	21,900		158,300	
BLUEBACK HERRING							
Bowline[b]	18,800	45,000	25,600	5,400	2	33,700	5
Indian Point[c]	1,000	37,500	155,800	258,300	89	637,400	85
Lovett	9,000	13,800	7,400	400	<1	800	<1
Roseton	6,400[d]	2,700	78,900	10,400	4	46,400	6
Danskammer	29,200	13,300	100,100	14,200	5	30,100	4
TOTAL	64,400	112,300	367,800	288,700		748,400	
BAY ANCHOVY							
Bowline[b]	4,400	4,900	3,700	3,800	20	7,400	4
Indian Point[c]	11,900	95,000	96,000	12,100	64	146,900	78
Lovett	4,800	4,700	1,600	400	2	1,200	<1
Roseton	1,100[d]	3,400	2,300	2,400	13	31,200	17
Danskammer	22,200	2,300	2,100	100	<1	1,300	<1
TOTAL	44,400	110,300	105,700	18,800		188,000	
ATLANTIC TOMCOD							
Bowline[b]	12,600	13,900	16,100	4,600	5	12,800	2
Indian Point[c]	28,300	375,700	78,600	34,200	34	747,800	92
Lovett	59,500	21,500	4,500	1,300	1	5,200	<1
Roseton	300[d]	4,300	4,800	7,200	7	19,500	2
Danskammer	647,000	155,900	46,900	54,600	54	26,900	3
TOTAL	747,700	571,300	150,900	101,900		812,200	
SUM OF ALL SPECIES	1,440,000	1,913,500	1,776,200	1,458,800		3,578,200	

[a] Total has been rounded to nearest 100.

[b] Unit I started commercial service in October 1972; Unit II started commercial service in May 1974.

[c] Sum of 3 Indian Point Units--Unit I was shut down in October 1974; Unit II started operation in June 1972; Unit III was operated March-December 1974 and started up again in January 1976.

[d] No sampling prior to July 1973. Limited plant operation until fall of 1974. Unit 2 in full commercial operation in September 1974, Unit 1 in December 1974.

Source: McFadden (1978)

plant will remain the primary impinger among Hudson River power plants.

4.182 Information relating numbers of fish impinged must be assessed relative to the total pupulation size, natural mortality rates, reproduction capability, and life history biology of a species to determine the significance of the impact from impingement. Conditional impingement mortality may be used as an initial measure of impingement impact on a population of fish. Conditional impingement mortality is defined as the percentage of juvenile fish of each species spawned that year that would have been killed if the only cause of death to juvenile fish was impingement resulting from operation of the power plants. The usefulness of this measure is that it estimates the impingement-related fractional reduction in year class abundance in the absence of other sources of mortality and compensation. Estimates of coniditonal mortality very depending on assumptions made in developing input data and scenarios (Barnthouse, 1979).

4.183 Estimates of conditional impingement mortality resulting from the operation of the Roseton, Bowline, and Indian Point stations are available only for conditions prevailing in 1974 and 1975 (Table 4-34). Neither Bowline Point nor Roseton were fully operational during 1974. In 1975, Indian Point Unit 3 was not operational. Based on these limited data, however, it can be seen from Table 4-34 that conditional impingement mortality, even with once-through cooling at all three of these power plants, was relatively low except for white perch. In most cases, the Utilities' estimates fell within the ranges independently estimated by the U.S. Environmental Protection Agency (Barnthouse and Van Winkle, 1979).

4.184 Seasonal and spatial variations in riverwide fish impingement are evident (Tables 4-35 and 4-36). White perch were impinged in greatest quantities at downriver power plants (Bowline, Lovett and Indian Point) during January through April, Roseton and Danskammer farther upstream from April through June or July, and once again in early fall, and at the Albany station (farthest power plant upriver) from June through October. Blueback herring exhibited some spring and strong fall impingement at the downriver plants and spring, summer, and fall impingement at the upriver plants. The impingement rate of alewifes was greatest at the upriver plants, and occurred almost exclusively during summer and early fall. Bay anchovy, a species found only in more saline water, was impinged strongly during mid- and late summer at the downriver plants. Very large impingement rates for Atlantic tomcod occurred at Danskammer during the winter. Downriver, impingement was greatest during the summer, occurring principally at Indian Point. A lesser peak in impingement occurred during the winter. The impingement patterns for

TABLE 4-34

ESTIMATES OF CONDITIONAL IMPINGEMENT MORTALITY (PERCENT) FOR THE 1974 AND 1975 YEAR CLASSES OF WHITE PERCH, STRIPED BASS, AND ATLANTIC TOMCOD, ASSUMING THREE ALTERNATIVE CLOSE-CYCLE COOLING CONFIGURATIONS

	CONFIGURATION					
	1[a]		2[b]		3[c]	
	LOW	HIGH	LOW	HIGH	LOW	HIGH
White perch (1974)						
Maximum range	2.7	15.0	3.0	17.7	4.2	23.7
Probable range	3.1	12.8	3.6	14.3	4.9	19.5
White perch (1975)						
Maximum range	1.3	4.2	1.9	6.1	2.4	7.8
Probable range	2.0	4.2	2.9	6.1	3.6	7.8
Striped bass (1974)	0.3	2.3	0.3	2.4	1.0	8.1
Striped bass (1975)	0.1	1.3	0.1	1.3	0.3	2.4
Atlantic tomcod (1974)	0.4	1.8	0.4	1.9	0.4	1.9
Atlantic tomcod (1975)	0.1	0.3	0.1	0.4	0.1	0.4

[a] Closed-cycle cooling at Bowline, Indian Point, and Roseton.

[b] Closed-cycle cooling at Bowline, and Indian Point; once-through cooling at Roseton.

[c] Closed-cycle cooling at Indian Point; once-through cooling at Bowline and Roseton.

Source: Barnthouse and Van Winkel, 1979.

TABLE 4-35

PERIODS OF GREATEST IMPINGEMENT FOR SEVERAL FISH SPECIES AT POWER PLANTS ON THE HUDSON RIVER ESTUARY

	POWER PLANT		
SPECIES	BOWLINE LOVETT INDIAN POINT	ROSETON DANSKAMMER	ALBANY
White Perch	Winter and Early Spring	Spring and Early Summer, Early Fall	Summer and Early Fall
Blueback Herring	Spring, Fall	Spring through Fall	Spring through Fall
Alewife		Summer and Early Fall	Summer and Early Fall
Bay Anchovy	Mid-to-late Summer		
Atlantic Tomcod	Summer, Winter	Winter	
Striped Bass	Winter and Early Spring	Summer and Early Fall	Summer and Early Fall

Source: Data presented in Barnthouse et al., 1977. Tables A5.4-1 through A5.4-5.

TABLE 4-36

MONTHS OF GREATEST AND LEAST IMPINGEMENT OF STRIPED BASS AT POWER PLANTS ON THE HUDSON RIVER

	MONTHS OF GREATEST IMPINGEMENT			MONTHS OF LEAST IMPINGEMENT		
POWER PLANT	1973	1974	1975	1973	1974	1975
Bowline Point	1,2,4,12	1-3	1,3,4,12	6,8-10	6-9	6,8-11
Lovett	4,8,11,12	1,2,4	1-4	1,5,7,10	5,7-9	5,7,8,10
Indian Point 1		1,3,4,12			6-9	
Indian Point 2	1,3,4,12	1-3,5	2-4,7,8	5,7,9,10	6,7,9-11	3,5,6,11
Roseton		5,6,10,11			1-4	
Danskammer 1 and 2	9-12	6-9		1-4	1-3,5	
Danskammer 3 and 4	9-12	6-9		1,3-5	2-4,11	
Albany		6-9			1-3,12	

Source: Appendix E, Table 5.5-3.

all of these species may be related to the migratory and seasonal behavior aspects of their life histories.

4.185 The temporal pattern of striped bass impingement at power plants along the Hudson River varied between the upstream stations and those farther downstream (Tables 4-35 and 4-36). For Bowline Point, Lovett, and Indian Point, impingement rates tended to be greatest during the winter and early spring (December through April) and least during May through October. At Roseton, Danskammer, and Albany impingement tended to be greatest from June through October or November and least from January through April. The reason for this pattern is not clear. One possibility is that downriver plants are impinging young-of-the-year striped bass during their first winter, while upriver plants are impinging yearling striped bass.

4.186 Information relating numbers of fish impinged must be assessed relative to the total population size, natural mortality rates, reproduction capability, and life history biology of a species to determine the significance of the impact from impingement. Conditional impingement mortality may be used as an initial measure of impingement impact on a population of fish. Conditional impingement mortality is defined as the fraction of a population killed due to impingement and is most accurately applied on a species year-class cohort basis. The usefulness of this measure is that it estimates the impingement-related fractional reduction in year class abundance in the absence of other sources of mortality and compensation. Estimates of conditional mortality vary depending on assumptions made in developing input data and scenarios (Barnthouse, 1979).

Cumulative Long-Term Impacts to Adult Fish Populations of the Hudson River

4.187 Mortality of fish eggs, larvae, and juveniles due to entrainment and impingement at power plants on the Hudson River (presented in previous sections) represents an immediate impact to each new year class of fish. As discussed, estimates of these parameters can be made with a fair degree of confidence based on available technology and procedures. At the heart of the dispute over the need for cooling towers at Bowline Point, Roseton, and Indian Point generating stations, however, is the long-term effect of the impact of entrainment and impingement mortality on the abundance of adult fish in the Hudson River. Estimation of the reduction in future adult population levels is difficult because of reasons related both to the present state of knowledge of fishery population dynamics, data required to test and apply present theories of fishery management, and problems with the adequacy of data presently available on fish stocks of the Hudson River.

4.188 At present, the Utilities have utilized two methods of estimating long-term impacts, both based on an extension of a current theory of population dynamics. The U.S. Environmental Protection Agency has criticized the underlying data and theory of the Utilities' presentation and has taken the position that the long-term impact on adult populations cannot be predicted from data presently available from the Hudson River and that theory and methods are unlikely to be developed in the near future that would allow accurate estimation of the impacts of entrainment and impingement mortality on adult populations.

Estimates by the Utilities of Long-Term Impacts to Fish Populations

4.189 The Utilities have used the Equilibrium Reduction Equation method and the Real-Time Life-Cycle Model as their two methods for predicting long-term impacts to adult fish populations (McFadden, 1977; McFadden and Lawler, 1977). The Equilibrium Reduction Equation method consists of entering mortality statistics reflecting power plant operation into an equation that predicts the percentage by which the particular fish population would be reduced on the average in the long term. Inputs to the equation are derived from data for a particular year. The prediction of long-term impact that is calculated represents the impact that would be expected if those same conditions occured every year in the future. The Equilibrium Reduction Equation cannot be used to predict the consequences of future changes in power plant operational conditions or the start-up of new power plants. Impact estimates for striped bass, white perch, Atlantic tomcod, and American shad have been made using this calculation.

4.190 The Real-Time Life-Cycle Model is a computer simulation that has been used in conjunction with the Equilibrium Reduction Equation to predict impacts resulting from plant operational patterns that vary from year to year and from new plants that are expected to commence operation in the future. To date, only estimates of impacts on striped bass are available from the use of this simulation.

4.191 The Utilities have based their impact estimates on data gathered from the Hudson River and on several theoretical considerations. These considerations are as follows:

- That the process of compensation is operating within the affected fish populations of the Hudson River.
- That an inverse relationship between growth rate and abundance of juvenile striped bass can be demonstrated as evidence of the existence of compensation.

- That hypotheses of natural population regulation concerning the relationship between the numbers of spawning adults and the numbers of offspring ultimately entering the fishery (stock-recruitment models) can be applied to fish species of the Hudson River as a way of estimating their compensatory response to additional mortality resulting from entrainment and impingement.

- That the Ricker model of stock recruitment is most appropriate for Hudson River fish species.

- That data from the Hudson River are adequate to estimate the parameters of the Ricker formulation, which is the basis for all estimates of long-term impact.

- That a value of 4 for the parameter α (used as an index of the magnitude of compensation) in the Ricker equation is a conservative estimate for application to the Hudson River situation.

These premises are discussed in turn below.

4.192 Demonstration of Compensation in Fish Populations. An important base on which the impact estimates of the Utilities rests is the degree to which compensatory mechanisms exist within the dynamics of the fish populations in the Hudson River. The existence of such mechanisms would tend to offset the effects of any additional mortality resulting from power plant operations. Compensation refers to the tendency of populations of living organisms to experience an increase in death rate or decrease in birth rate as the number of organisms increases. Conversely, compensation also requires a decrease in death rate or increase in birth rate as population size declines (McFadden, 1977). A number of mechanisms could be responsible for this effect. These include changes in competition for resources, predation, or cannibalism (McFadden, 1977). The position of the Utilities is that empirical demonstration of compensation acting in fish populations is well documented in the scientific literature and that compensatory mechanisms may act rather strongly to offset increased mortality from power plants (McFadden, 1977). In general, the controversy over compensation has not involved its existence but rather how strongly it operates in fish populations.

4.193 The most recent data to demonstrate compensation operating in the striped bass and white perch populations in the Hudson River have been presented in Utility Exhibits 49 and 50 (undated) submitted as part of the Utilities' case in the Adjudicatory hearings of Environmental Protection Agency. In both of these investigations, the negative correlation found between population size and growth rate of juveniles was presented as evidence for the operation of compensation that is, growth rate is not constant but is affected by the number of juvenile fish percent during any year.

4.194 In Utility Exhibit 50, an index of young-of-the-year population size striped bass and white perch was obtained by averaging catch-per-unit effort values for day bottom trawls at three river stations near the Bowline Point generating station for September, October and November. The index of population size was the grand average for the three monthly means. The index of growth was the mean total length attained by a random sample of young-of-the-year fish collected from 1971 through 1976 by beach seine and bottom trawl from the Bowline Point vicinity at or near the end of the growing season (October for striped bass, November for white perch). This index of growth was negatively related to the natural logarithm of fall population size when variations in river flow for February through August were held constant (flow index).

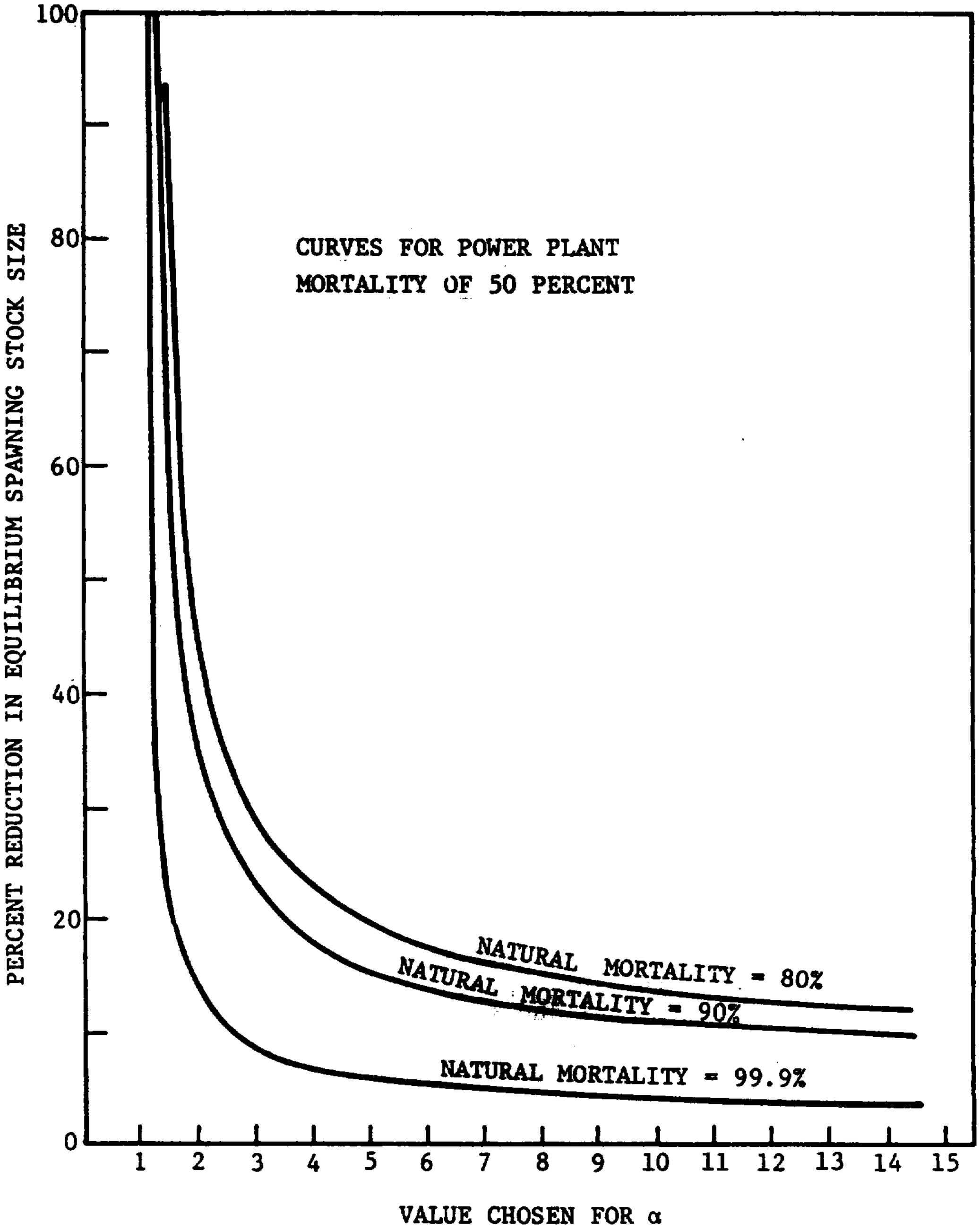
4.195 In Utility Exhibit 49, riverwide data were used to estimate population and growth of young striped bass. When the effects of water temperature on growth were taken into account, a significant inverse relationship between fish population size and growth rate was found during July and August for 1965 through 1976.

4.196 Justification for Using Stock-Recruitment Theory and the Ricker Formulation. Given that the process of compensation can be demonstrated as occuring within some fish species in the Hudson River, the Utilities feel that a proposed theory of natural population regulation that is concerned with the relationship among the size of an adult fish population (spawners) and the size of the offspring population (recruits) at some specified age (often the age at which they become vulnerable to capture by the commercial fishery) can be applied with confidence as the basis for the estimation of long-term impact to the fish stock (McFadden, 1977). These theories have been called spawner-recruit or stock-recruitment models of population dynamics. Among the various theories that have been mathematically defined, the Utilities feel that the formulation proposed by Ricker (1954) best describes the dynamics of the fish species effected by power plant operation in the Hudson River because the Ricker formulation emphasizes the compensatory nature of the numerical relationship between parent fish and the progeny they produce and the importance of the earlier life history stages in compensation (McFadden, 1977, section 10.3). Because the original Ricker formulation applies to a single age spawning population, the Utilities have developed an extension of the theory for use with multiple age spawning populations such as striped bass. The finding of that analysis was that the original formulation provided a conservative estimate of power plant impact (McFadden and Lawler, 1977).

4.197 Evaluation of the parameter α in the Ricker Formula. An aspect of the Ricker formulation that is very important to the estimate of the magnitude of power plant impacts on adult fish populations is the value of the parameter α (alpha), which can be used as an index of the amount of compensation in a particular species. The value of α can be estimated by fitting the Ricker formula to a plot of a time series of data of adult population size (adult stock) versus the resulting progeny population size (recruits). Catch-per-unit-effort data for the commercial striped bass fishery on the Hudson River have been used to estimate the size of the adult stock and corresponding progeny with various lag times between parent and progeny generations used in the analysis. The most recent analysis is given in Utility Exhibit 58. In this analysis, values of from 2.7 to 5.3 were calculated for striped bass. These calculations were considered by the utilities to support the previous utilities contention that an α value of 4.0 used in impact estimates is a conservative value (McFadden, 1977; McFadden and Lawler, 1977). The value of 4.0 for α is a particularly important aspect of the Utility impact analysis because the estimate of long-term reduction in the adult population of striped bass using the Utilities' method increases very rapidly with values of α smaller than 4.0, as shown in Figure 4-9.

4.198 The Real-Time Life Cycle Model. The Real-Time-Life-Cycle Model is a computer simulation that has been used by the Utilities to predict long-term impacts to striped bass under changing environmental and power plant operational conditions (McFadden and Lawler, 1977). The model utilizes a simulation of the hydrodynamics of the Hudson River estuary to determine distribution of striped bass eggs and larvae and a life cycle model to predict the long-term reduction in the size of the adult population. Details of the model are given in McFadden and Lawler (1977).

4.199 In the young-of-the-year portion of the Real-Time Life-Cycle Model, both vertical and longitudinal migration rates are calculated directly from field data on distribution of eggs and larvae. These migration rates are combined with total egg production, mortality rates, entrainment and impingement rates, and river transport processes to generate standing crop estimates throughout the year. Recruits to adult age-group 1 (one-year-olds) are derived from the number of juvenile fish remaining on day 365 after first spawn. The number of recruits, together with density-independent survival rates, is then used to generate an adult population for age groups 2 through 14. Given this total adult population, the percentage of females in it, and the average fecundity and maturation within each age group, the total number of eggs that will be produced by the population is predicted; this total then serves as an input to the young-of-the-year model to generate a new group of one-year-olds, and so on.



Source: McFadden, 1977.

FIGURE 4-9
EFFECT OF PARAMETER α FROM THE RICKER STOCK-RECRUITMENT RELATIONSHIP ON ESTIMATES OF PERCENT REDUCTION IN EQUILIBRIUM SPAWNING STOCK OF STRIPED BASS

4.200 Data requirements of the model are parameters related to river geometry and mass transport, biological factors, and power plant operation. In the river transport model there are 29 longitudinal segments divided into 2 vertical segments of equal depth. In addition, a correlation was developed between the 12 sampling regions of the field surveys of the distribution of eggs and larvae and the 29 segments of the model, so as to permit direct input of field estimates of egg production and comparison of output with Texas Instruments estimates of standing crops for later life stages.

4.201 The simulation of the hydrodynamics of tidal action in different layers of the river requires estimates of the maximum flows in the upper and lower layers during the ebb and flood tides as well as net flows. These flows were obtained and/or calculated from various field surveys, from modeling studies which employ a three dimensional model of the Hudson and, in particular, from 1974 and 1975 flow data.

4.202 Biological parameters include egg production, natural mortality rates and duration of life stages, compensation parameters, larval and juvenile migration, and adult survival and reproduction parameters. Temporal and spatial distribution of eggs, larvae and juveniles as measured during 1974 and 1975 were used to calibrate the model. The compensation function is based on the Beverton-Holt formulation and is calibrated through the Ricker stock-recruitment analysis for an alpha value of 4.0.

4.203 Parameters related to power plant operation include plant location, plant flow rates, impingement rates, and factors related to entrainment. The entrainment factors include the portion of the water mass subject to entrainment, the percentage of organisms in the river that are drawn through each power plant, the fraction of entrained organisms that survive, and the percentage of entrained water that is recirculated.

4.204 Year-to-year variation in environmental and biological factors has been provided for in the model through random variation in freshwater flow, the temporal and spatial distribution of striped bass spawning, and the percentage of organisms in the river that are drawn through each plant. Random sequences of conditions used are based on historical data.

4.205 Estimates by the Utilities of Long-Term Reduction in Fish Stocks. Estimates by the utilities of the long-term reduction in the size of the adult fish stocks in the Hudson River have been made using the Equilibrium Reduction Equation only for striped bass, white perch, Atlantic tomcod, and American shad for 1974 and 1975 (Table 4-37). The impacts of the Danskammer and Lovett Plants are

TABLE 4-37

UTILITY ESTIMATES OF LONG-TERM REDUCTION IN SOME ADULT FISH STOCKS AS ESTIMATED WITH THE EQUILIBRIUM REDUCTION EQUATION

POWER PLANT	PERCENT REDUCTION IN EQUILIBRIUM LEVEL OF ADULT STOCK RESULTING FROM					
	ENTRAINMENT LOSSES		IMPINGEMENT LOSSES		COMBINED LOSSES	
	1974	1975	1974	1975	1974	1975
	STRIPED BASS[d]					
Bowline[a]	1.9	2.2	2.5	0.6	4.4	2.8
Roseton[b]	NE	2.6	NE	<0.1	NE	2.6
Indian Point[c]	4.2	4.4	0.6	1.0	4.8	5.4
Combined	6.1	9.2	3.1	1.6	9.2	10.8
	WHITE PERCH[e]					
Bowline[a]	1.6	1.3	2.2	NE	3.8	NE
Roseton[b]	NE	1.5	0.2	NE	0.2	NE
Indian Point[c]	2.9	2.4	7.1	NE	10.0	NE
Combined	4.5	5.2	9.5	NE	14.0	NE
	ATLANTIC TOMCOD[f]					
Bowline[a]	NE	2.1	<0.1	NE	NE	NE
Roseton[b]	NE	<0.1	<0.1	NE	NE	NE
Indian Point[c]	NE	0.5	1.0	NE	NE	NE
Combined	NE	2.7	1.0	NE	NE	NE
	AMERICAN SHAD[g]					
Bowline[a]	0.6	NE	0.8	NE	1.4	NE
Roseton[b]	NE	NE	0.1	NE	0.1	NE
Indian Point[c]	1.7	NE	0.8	NE	2.5	NE
Combined	2.3	NE	1.7	NE	4.0	NE

[a] Unit 2 activated May 1974

[b] Unit 2 activated September 1974, Unit 1 activated in December 1974

[c] Includes small effect from Unit 3 in some estimates

[d] $\alpha = 4.0$ [e] $\alpha = 3.5$ [f] $\alpha = 4.5$ [g] $\alpha = 2.0$

NE = not estimated

Note: date in column heading is year class

Source: McFadden and Lawler, 1977.

not included in the calculation since the utilities believe that they have been operating long enough to have their effect reflected in the baseline condition. As discussed above, a value of $\alpha = 4$ was used for striped bass. Values of α for the other species were not determined empirically, but were chosen from among curves presented in Ricker (1975), based on what is known about related species (McFadden and Lawler, 1977). If the same power plant and natural ecological conditions actually occurring during 1974 and 1975 were to continue through the operating lives of the plants, the utilities estimated that the fish populations would be reduced by the given percentages below the average level that characterized the stock before the new power generating units were activitated.

4.206 The predicted reduction in the striped bass population was in the range of 9 to 11 percent (Table 4-37). For the two years, the main impact was due to entrainment losses with about one-half of the entrainment impact occurring at the Indian Point generating station. Impingement impact was variable among plants for the two years.

4.207 Reduction in the white perch population was estimated to be 14 percent based on 1974 data. Impingement losses were of greater magnitude than entrainment losses. The greatest effect of impingement was due to the Indian Point station.

4.208 Limited data are available for Atlantic tomcod. Stock reduction due to entrainment conditions prevailing in 1975 was estimated to be 2.7 percent, most of which was due to the Bowline Point plant. Reductions due to impingement in 1974 was estimated to be 1.0 percent, almost all of which was due to the Indian Point plant.

4.209 Simulation of 40 years of operation of Indian Point units 2 and 3, Roseton units 1 and 2, and Bowline Point units 1 and 2 using the Real-Time Life-Cycle Model gave a predicted 8 percent reduction in the equilibrium level of the adult stock of striped bass (McFadden and Lawler, 1977). Indian Point unit 1 and the Lovett and Danskammer plants were not included in the model run because their impact was believed to be already reflected in the baseline conditions.

4.210 U.S. Environmental Protection Agency Review and Analysis of Utility Estimates of Long-Term Impacts to Adult Fish Populations. The Utilities have used data from the Hudson River and various statistical tests to support and implement the theoretical basis of their analysis of the impacts of power plant operations, as described above. The following data and statistical evaluations are important to the analysis of the utilities.

- Data on abundance and growth of juvenile and young-of-the-year striped bass and white perch are adequate to demonstrate a negative relationship between abundance and growth, thus demonstrating the existence of compensation in these populations.

- The catch-per-unit-effort data from the Hudson River are adequate to estimate the size of the parent stock and recruit resulting recruit population as input to the Ricker stock-recruitment model.

- The Ricker model fits the spawner-recruit data with satisfactory statistical significance.

- Statistical analyses of data from the Hudson River indicate that a value of $\alpha = 4$ is conservative for striped bass and that values for other species can be estimated adequately.

4.211 The U.S Environmental Protection Agency (EPA) and their consultants have evaluated the Utility analyses in testimony dated April and May, 1977. In general, the EPA has determined that:

- The demonstration of a negative correlation between juvenile population size and growth does not hold up when the statistical basis of the analysis is examined and data for 1977 are added to the analysis

- The questionable accuracy of the catch record gathered by the National Marine Fisheries Service and the estimate of fishing effort calculated by the Utilities make the reliability of these data insufficient for use in determining adult spawning and resulting progeny population sizes

- There is no valid basis for selecting the Ricker model over other models of population dynamics (such as the Beverton-Holt formulation) that could also apply to the fish species of the Hudson River

- The fit of the Ricker model to the spawner-recruit data from the Hudson River is poor and is no better than the fit to random numbers

- Because of the above considerations, the Utility estimates of the parameter α derived from the fitting of the Ricker curve to the spawner-recruit data are unreliable

- Because it is an unreliable estimate, the value of α for striped bass could be much lower than the value of $\alpha = 4$

estimated by the Utility, which would result in a much larger estimate of long-term reduction in the equilibrium level of the adult striped bass population than the Utilities' estimate of 8 to 10 percent.

Each of these findings is discussed in more detail below.

4.212 Analysis of the Utilities' Demonstration of Compensation. The Utilities' demonstration of an empirical relationship between population size and growth of juvenile and young-of-the-year striped bass and white perch has been presented in Utility Exhibits 49 and 50. In Utility Exhibit 49, riverwide beach seine data for juvenile striped bass were utilized to estimate population size and growth. The effects of variations in growth rate due to water temperature were accounted for by including the rate of Hudson River temperature increase from 16 to 20 C as a variable in these regressions. A statistically significant negative correlation was found between population size and incremental growth and relative growth of juvenile striped bass when the effects of temperature were held constant.

4.213 In Utility Exhibit 50, an index of young-of-the-year population size (year class strength) was obtained by averaging catch per unit effort values for daytime bottom trawls taken from September through November at three stations in Haverstraw Bay near the Bowline Generating Station. The logarithm of population size rather than population itself was used as an index of fish abundance. The analysis in Utility Exhibit 50 took variations in river flow between February and August into account as a variable affecting growth, as opposed to the analysis in Utility Exhibit 49, in which the effects of temperature on growth were factored out. Statistically significant negative relationships between length and the logarithm of population size, once variations in river flow were accounted for, were found for striped bass and white perch for the years 1971 through 1976.

4.214 Examination of the Utilities' demonstration of an empirical relationship between population size and growth of young-of-the-year and juvenile striped bass and white perch has been presented in Barnthouse (1979), Rohlf (1979), and Fletcher and Deriso (1979). In general, these authors express serious reservations about the quality of the data on fish population size and growth and on the statistical analyses used to infer the negative relationship between population size and growth.

4.215 Barnthouse (1979) and Rohlf (1979) have reanalyzed the data in Utility Exhibit 50 by including data for 1977. In both cases, the significant relationship between growth and population size for striped bass disappears when the datum point for 1977 is added to the regression analysis. However, a significant negative correlation was still obtained for white perch.

4.216 Fletcher and Deriso (1979) believe that the measure of abundance for striped bass (based on data from September through November) is not appropriate, since the length of striped bass from October samples were used as indexes of growth. They feel that data for November would be irrelevant to a measure of growth based on data for October and that the analysis should be based on abundance data only from samples obtained prior to November.

4.217 Rohlf (1979) has questioned the use of the type of index of river flow chosen for use in Utility Exhibit 50 (seven month period principal component score), stating that such an approach has no clear biological basis. He feels that total flow during the growing season or a weighted average flow based on some demonstrated biological importance of flow during different months would be a more reasonable way of including the effects of river flow in the analysis.

4.218 Pooling of data may have also affected the results obtained. Data for the years 1974 through 1976 used on the analysis in Utility Exhibit 50 were from samples that had been pooled for all stations and types of collection gear. Barthouse (1979) has noted that this pooling would not introduce bias into the analysis if the average lengths of fish collected with each gear type were the same or if the distribution of the total catch among the various gears were the same from year to year. Since these conditions were not met, it is as equally possible that errors introduced by the pooling procedure obscured the true relationship between population size and growth as it is that the errors introduced a spurious correlation and that in reality no relationship between population size, growth, and river flow exists.

4.219 Barnthouse (1979) and Rohlf (1979) have also pointed out problems in the analysis of the relationship between population size and growth presented in Utility Exhibit 49. Because the beach seine data for striped bass for 1969 through 1972 were only for the Indian Point area, these data have been converted, using riverwide data for 1973 through 1975, to be equivalent to riverwide samples. There is so much variation in the technique used to adjust the data, however, that Barnthouse (1979) feels that little confidence can be placed in the derivation of the adjustment factor. As a result, the adjusted population levels determined for 1969 through 1972 could be as much as from one-half to twice the value estimated for each of these years. Excluding these years and recalculating the regression analysis given in the Exhibit results in no statistical relationship between population size and growth.

4.220 The datum point for 1969 has been found to be particularly important to the analysis in Utility Exhibit 49 (Barnthouse, 1979; Rohlf, 1979). Data for that year were from the Indian Point region only. The sampling effort was also unusually low. Analysis of residuals (a statistical method of assessing the relative importance of the datum point for each year in determining the fit to the multiple regression model) indicated that the datum point for 1969 has a disproportionally high contribution to the fit of the regression model compared to other points (Rohlf, 1979). When the 1969 datum point is excluded and the multiple regression recalculated, no statistically significant correlation between population size and growth is obtained (Barnthouse, 1979).

4.221 Barnthouse (1979) and Rohlf (1979) have compared the analyses presented in Utility Exhibits 49 and 50, because one analysis considered temperature but not river flow and the other considered river flow but not temperature as the important environmental variable to be accounted for in the regression analysis. Since both analyses are examining the same population, the growth and abundance indices determined in both analyses should be positively correlated with each other. As calculated in Barnthouse (1979), the correlation of the incremental and relative growth indices of Utility Exhibit 49 to the growth index used in Utility Exhibit 50 was not statistically significantly different from zero for striped bass. The correlation of striped bass population size was zero or negative. Similar comparisons of the white perch analyses found no correlation between population size indices. One comparison of growth indices did give a significant positive correlation. Barnthouse (1979) feels that a finding of strong positive correlations between the sets of growth and abundance indices developed in the two Exhibits would have provided strong support for the results and conclusions presented. He feels that the general absence of such correlations casts serious doubt on the validity of the analyses in both Exhibits.

4.222 Rohlf (1979) noted the inconsistency in the conclusions of Utility Exhibits 49 and 50 because different factors affecting growth were used in each. The analysis in Utility Exhibit 49 used population size and water temperature as predictors in the regression analysis of the effects on growth, while the analysis carried out in Utility Exhibit 50 used the logarithm of population size and river flow as predictors. When the regression analysis of data from Utility Exhibit 49 was recalculated using the predictors from Utility Exhibit 50, it was found that the predictors used in Utility Exhibit 50 were poorer predictors of growth rate than the predictors actually used in Utility Exhibit 49. The same conclusions were reached when the predictors from Utility Exhibit 49 were applied to the data in Utility Exhibit 50. The inconsistencies were felt to be a result of the small sample sizes available (Rohlf, 1979).

4.223 Another statistical problem with the analysis in Utility Exhibits 49 and 50 is that the temperature and flow variables used were selected on their observed ability to predict population size using the same set of data. Rohlf (1979) states that this invalidates the probabilities found in all tests of significance, since these tests they are conditional on the preliminary results of the same set of data. Validation of these results using an independent set of data would be necessary.

4.224 <u>Quality of the Catch-per-Unit-Effort Data from the Hudson River</u>. As discussed earlier, the Utility analysis of long-term impact on fish populations is based almost entirely on the use of the Ricker stock-recruitment model. Because the parameters of the Ricker formulation are calculated from the fit of the model to estimates of the population size of adult spawners and their resulting progeny, the quality of the data used to estimate yearly population size in the Hudson River is very important to the analysis. The Utilities have utilized a portion of the commercial catch data from the Hudson River available from the National Marine Fisheries for the years 1931 through 1975 (McFadden, 1977; McFadden and Lawler, 1977; Utility Exhibit 58). These data and an independent measure of the fishing effort expended in landing the catch are used to calculate catch-per-unit-effort as the measure of stock size.

4.225 Fletcher and Deriso (1979) have examined the quality of the available catch-per-unit-effort calculations of the utilities. These authors have noted that the catch statistics are not actual catch data but are estimates by selected fishermen of what they recall their catch of shad and striped bass to be from the year previous to each survey. Since the catch data survey was principally concerned with the shad fishery, the Utilities' analysts used a constant adjustment factor for years prior to 1965 to correct the catch data to reflect the landings of those fishermen whose catches consisted principally of striped bass and, therefore, were not included in the survey. Fletcher and Deriso (1979) have also noted that the data on effort expended in landing the catch are not actual measurements of the effort expended by the fishermen included in the survey but were calculated independently from fishing gear registration records and state laws regulating gear use.

4.226 The uncertainties associated with the catch and effort data have been reviewed in McFadden (1977), Fletcher and Deriso (1979), and Goodyear (1979a). There are seven main sources of error as summarized in Fletcher and Deriso (1979).

- The anecdotal nature of the data collection method is an unreliable indicator of catch.

- The sampling method is inconsistent because of changes in interviewers.

- The fishermen surveyed are not held accountable for the accuracy of their information.

- There were no independent methods of verification of the data.

- The effort figures to be paired with the catch figures are not the efforts actually expended by the fishermen from whom the catch figures were obtained.

- A constant correction factor was applied to the data prior to 1965.

- The assumption of 100 percent use by fishermen of all gear registered in any year and of 100 percent use by every fisherman of the entire statutory fishing season is unrealistic.

4.227 Because of the requirement in the stock recruitment concept for pairing estimates of adult the population size of spawners with those of recruits several years later, the number of data points obtainable from the catch record is fairly small. As a result, the fit of the Ricker curve to the estimates of the size of the adult spawning stock and resulting progeny that are calculated from the catch and effort data is very sensitive to any errors in the few points available. Fletcher and Deriso (1979) state that the sources of error in catch and effort data cited above make the level of reliability of the data insufficient for their use in estimating spawning stock and recruit population size.

4.228 Analysis of the Use of the Spawners-Recruit Concepts as the Basis for Impact Analysis. In the Utilities' analysis, the estimates of spawning stock and resulting progency population size are necessary inputs to the Ricker spawner-recruit model used to estimate the long-term reduction in adult equilibrium population size due to entrainment and impingement mortality at power plants on the Hudson River. The use of the Ricker spawner-recruit model as the basis for the estimate of impacts is justified by the Utilities on the grounds that stock recruitment principles are widely used in fishery management. General documentation is presented in McFadden (1977), and specific examples of spawner-recruit models considered to have been used in management of fish stocks are given in Utility Exhibit 59. Fletcher and Deriso (1979) have reviewed these examples by corresponding with those agencies cited in Utility Exhibit 59 as using spawner-recruit models in their management activities. All replies to these inquiries indicated that, contrary to the claims of the Utilities, spawner-recruit models were not used in the direct management of fish stocks because of the general unreliability of such models. Fletcher and Deriso (1979) also noted that some of the models listed in Utility Exhibit 59 are not even spawner-recruit models.

4.229 Analysis of the Use of the Ricker Spawner-Recruit Relationship for Fish Populations of the Hudson River. In applying the spawner-recruit concept as the basis for impact estimate, the Utilities have chosen the Ricker spawner-recruit model as the particular formulation that describes the dynamics of fish populations in the Hudson River. The Utilities contend that a statistically significant fit of the Ricker curve can be made to the estimates of the size of the adult and resulting progeny populations of striped bass. From the resulting fit of the model to the data, an estimate can be made of the value of the parameter $\underline{\alpha}$, the value of which is important in estimating long-term reduction in the equilibrium level of the adult population. Documentation of the Utilities' analyses are presented in McFadden (1977), McFadden and Lawler (1979), and Utility Exhibit 58.

4.230 The fit of the Ricker model to the spawner and recruit data presented by the Utilities has been examined by several consultants to EPA (Christensen et al., 1979; Goodyear, 1979; Robson, 1979; Rohlf, 1979). The model was found to fit the available data very poorly.

4.231 Rohlf (1979) recalculated the regression fits of the Ricker curve to the data presented in Utility Exhibit 58 and found that the Ricker model fitted the data very poorly, which was in contrast to the findings presented in the Exhibit. The inclusion in the regression of a variable to account for the effects of river flow only slightly improved the fit of the data.

4.232 Robson (1979), after correcting for statistical defects in the Utility analysis found that the Ricker model provided a poor fit to the data using 4, 5, 6, or 7 year differences between the parent and recruit generations. Except for the analysis using a five year difference, these models were not better than, and, in several cases, worse than a model specifying that no relationships exist among recorded yearly catches. Arranged in rank order, the spawner-recruit data were found to be compatible with the assumption that they constitute a random sample from a log-normal distribution.

4.233 Similar results were obtained by Goodyear (1979), who stated that a large part of the observed fluctuations in the catch data used to derive estimates of spawner and recruit population size is probably a result of random factors that affect the reported catch data or the striped bass population itself rather than a result of compensation operating within the population. To test this, he fitted Ricker curves to random sets of spawner-recruit data base on catch statistics for striped bass from the Hudson River used in the Utility analysis. With the exception of the case using a five year time lag between spawners and recruits, results of these curve fittings to random data were similar to those fits obtained in the Utilities' analysis, indicating that the Utilities' analysis is also consistent with the results that would be expected from regression of random data (e.g., no relationship exists between the size of the adult spawning population and the resulting progeny population).

4.234 The potential significance of the regression fitted to a five year difference between spawners and recruits suggested by the findings of Robson (1979) and Goodyear (1979) was also found to be unreliable because this lag is biologically unreasonable for the Hudson River striped bass population. Christensen et al. (1979) have investigated the use of the five-year lag used by the Utilities to pair estimates of spawners with recruits to the more usual generation time approach, which would require longer lag times. The Utility analysis (called the proxy approach) is based on the belief that striped bass older than 5 years old represent, under equilibrium conditions, the contribution to spawning of 5 year olds later in life. The generation time approach holds that the best pairing of spawners and recruits is the lag time closest to the generation time of the population. The generation time is approximately the age by which a given "average" female fish has contributed one-half of her total expected lifetime egg production.

4.235 Christenson et al. (1979) have tested the reliability of the proxy approach against the generation time approach by fitting the Ricker curve to a simulated set of spawner-recruit data in which the generation time is actually 7 years, but for which the appropriate lag using the proxy approach would be 5 years. A value of $\alpha=10$ was specified for the simulated set of $\underline{\alpha}$ data. For all cases tested, the match of the fitted Ricker curve to the known underlying Ricker curve using a seven-year lag to pair spawners and recruits was always better than the match obtained using a five year lag, indicating that the generation time approach is superior to the proxy approach.

4.236 Analysis of the Value of α for the Ricker Curve. Once the Ricker curve has been fitted to the data on spawners and recruits, the value of the parameter $\underline{\alpha}$ can be determined. The value of this parameter is used by the Utilities as an index of the amount of compensation in the fish populations of the Hudson River and is entered into the Equilibrium Reduction Equation to determine the long term reduction in equilibrium population level of fish populations. Determinations by the Utilities of the value of utilizing data from the Hudson River are presented in McFadden (1977), McFadden and Lawler (1977), Utility Exhibit 58, and Utility Exhibit 137 (1978). A value of α =4 has been concluded by the Utilities to be a conservative estimate for the striped bass of the Hudson River. The reliability of this estimate is of critical importance to the impact analysis because values of α less than 4 would result in estimates of population reduction much larger than those calculated using the value of α =4. Use of values of α greater than 4 would not result in impact estimates much less than those predicted using α =4 (see Figure 4- 9).

4.237 The U.S. Environmental Protection Agency and their consultants have evaluated the Utility estimates of α in Christensen et al. (1979), Fletcher and Deriso (1979), Goodyear (1979), and Ricker (1979). In general, these investigators have found that the estimate of α =4 for striped bass is unrealiable and that the value of α could be much less.

4.238 Fletcher and Deriso (1979) and Ricker (1979) have both calculated α values for striped bass of less than 2. Fletcher and Deriso (1979) utilized Utility beach seine data as estimates of recruits. Spawners were estimated from catch data, but the pairing of spawners with recruits was adjusted by two years based on an analysis of the age composition of the catch. A value of α = 1.32 was calculated. Use of this value in the equilibrium reduction equation would result in an estimate of reduction of 80 percent in the equilibrium population level of adults. Eliminating a questionable datum point and recalculating, gave an estimate of α = 1.604, which would result in an estimate of a 52 percent reduction in the equilibrium level of adults. The two calculations also indicate the large sensitivity of the Utility method to small changes in the value of α when α is small. Ricker (1979), working from the premise of Gulland's Rule (1970, 1971), calculated a value of α = 1.95.

4.239 Goodyear (1979) fitted Ricker curves using the Utilities' method to random sets of spawner-recruit data based on catch statistics for striped bass from the Hudson River. Values of α of from 2.74 to 4.28 were calculated from these data fits. Because such a set of random data can result in values of α similar to the Utilities' estimate of α =4, Goodyear states that the parameter estimate by the Utilities is unreliable and should not be used to forecast the long-term reduction in adults resulting from power plant mortality.

4.240 The reliability of the estimate of α has also been examined by Christensen et al. (1979). Their approach, called validation analysis, involves fitting a Ricker curve using the Utilities methods to a simulated spawner-recruit data set for which the underlying value of α is known and comparing the value of α estimated from the fitted curve to the known value. The simulated time series of data utilized in the procedure is based on the salient characteristics of the Hudson River catch data used by the Utilities in their analysis. The rational behind the validation procedure is that if the predetermined value of α could be estimated from the curves fitted to the simulated data using the Utilities' methods, then it could be concluded that the utility curve fitting technique might be a reliable method of parameter estimation. If the values of α estimated from curves fitted to the simulated data sets were very dissimilar to the known true α for the data, then little or no confidence could be placed in the ability of the curve fitting technique to predict the value for real data from the Hudson River. The general conclusion of the study was that the Utilities' curve fitting exercise was inappropriate to the problem and produced misleading results, and thus the estimates of α obtained are unreliable to the point of being useless. The following specific conclusions were reached:

- For low true simulated values of α (1.0 or 1.25) in a simulated set of data, the curve- fitting exercise consistently tended to overestimate the value of α. True values of α of 5 or more were usually under estimated.

- Changes in the estimate of α were unresponsive to changes in the true underlying value of α for the simulated set of data. As the true value of increased over the range of 1.25 to 20, the mean value of the estimated α values increased from about 2 to 3 for a true of 1.25 to about 4 to 6 for a true α of 20. Individual estimated values showed considerable variation.

- Both the proxy approach and the generation time approach of pairing spawners and recruits provided equally poor estimates of α from the simulated data set.

- Adding a variable to the curve fitting procedure to account for the effects of variation in river flow had very little effect on the estimates of the value of α.

4.241 Analysis of the Real-Time Life-Cycle Model. The Utilities' Real-Time Life-Cycle Model has been reviewed by Golumbek et al. (1979). The opinion of these authors is that the model is not a reliable tool for making sound fisheries management decisions. The reasons for this opinion are discussed below.

- The conditional entrainment mortality rate for striped bass loss predicted by the model for 1974 and 1975 (data against which model output is validated) is probably underestimated by 23 to 24 percent. This is because the model tends to move yolk-sac and post yolk-sac larvae to regions of the river below the regions containing the power plants. This finding is supported by the poor correlation of distribution of these larval stages as predicted in the model with field data gathered from the Hudson River.

- Because the compensation included in the model cannot be verified with field data (see earlier sections above), the prediction of total mortality is probably an underestimate.

- Contrary to the Utilities' arguments, Golumbek et al. (1979) believe that the effects of the operation of the Lovett and Danskammer plants should be included in this model.

- The predictions of future impacts are not valid because of the uncertainties associated with utilizing the Ricker formulation and an $\underline{\alpha}$ value of 4.0, as discussed earlier.

- The one-dimensional transport model used in the stochastic modeling of future conditions is invalid.

- The independence among egg production and early life stage survival in the model is inconsistent with other testimony of the Utilities.

- Use of the Beverton-Holt compensation function in the model is inconsistent with the use of the Ricker function elsewhere in the Utilities' analyses.

- Use of variation in the freshwater flow in the model, while keeping life stage durations and early life stage survivals constant, is inconsistent with other Utility analyses that claim these three processes are related in the Hudson River.

- Application of compensation in the model after year-class strength is set is inconsistent with other testimony of the Utilities.

Contribution of Hudson River Striped Bass to the Atlantic Coastal Population

4.242 Recent data gathered by Texas Instruments (1976) has narrowed the range of previous estimates of the contribution of the Hudson River striped bass stock to the Atlantic coastal population. Analysis of these data (Table 4-38) by Texas Instruments personnel indicated that the Chesapeake Bay stock contributed the largest share of the total coastal population between Cape Hatteras, North Carolina and Maine. The proportion of Hudson-spawned fish increased within

TABLE 4-38

PERCENT CONTRIBUTION OF STRIPED BASS FROM THREE SPAWNING RIVER SYSTEMS TO THE ATLANTIC COASTAL POPULATION

COASTAL REGION	SPAWNING STOCK		
	HUDSON RIVER	CHESAPEAKE BAY	ROANOKE RIVER
Atlantic coast north of Cape Hatteras	7-23	66-90	3-11
Western half of Long Island Sound and the New York Bight	15-32	63-84	1-5
Cape May to the New York Bight and Maine to Western Long Island Sound	0-19	68-96	4-13

the western Long Island Sound-New York Bight Region to a maximum of 15 to 32 percent. The Hudson River is the predominant source for sub-legal size striped bass, collected in the Long-Island Sound-New York Bight Region (see Appendix D).

4.243 The data presented in Table 4-38 are discussed in more detail in Barnthouse et al. (1977). The values given are presented as a range because staff of the Oak Ridge National Laboratory felt that not enough information is yet available to evaluate independently the data analysis carried out in by Texas Instruments (1976).

Impacts to Endangered or Threatened Species

4.244 The shortnose sturgeon, an endangered species, and the Atlantic sturgeon, considered threatened, occur in the Hudson River and may be affected by power plant operation. Although five power plants are found along the Hudson River within the spawning range of the Atlantic sturgeon, it appears that very few eggs and juveniles are entrained (Central Hudson Gas and Electric 1977; Orange and Rockland, 1977; Lawler and McFadden, 1977). Available data presented in Table 4-39 indicate that less than 1 percent of Atlantic sturgeon juveniles are presently impinged by Hudson River power plants (total juvenile population estimated at 100,000) (Dovel, 1979). However, it is likely that a higher percentage may be impinged as a result of new units coming on-line at Indian Point. Dovel (1979) estimates that more than 1 percent of the juvenile population may be impinged annually at Indian Point alone. Although many sturgeon impinged at Bowline Point and Roseton are returned to the river alive there may be significant sublethal effects resulting in additional mortality or population reduction. Sturgeon impinged at Indian Point are not returned to the river alive.

4.245 It has been reported by Huff et al. (as cited in Dovel, 1979) that 22 shortnose sturgeon were impinged by Hudson River power plants between 1972 and 1976. However, Dovel has stated that this is likely to be an underestimate. Three of the 22 shortnose sturgeon impinged were longer then 60 cm, demonstrating that mature sturgeon may be eliminated from the population by power plants. Few shortnose sturgeon eggs, larvae, and juveniles are entrained by the Hudson River power plants under consideration in this document.

Sent already

4.246 Both species of sturgeon found in the Hudson River have been negatively affected by human activities that have involved alteration of spawning/brooding habitats, degradation of water quality, and overfishing. This has resulted in severe reductions below historical population levels. Sturgeon populations are especially susceptible to mortality because an individual must survive for up to 12 to 18 years before any reproduction is possible. Hudson River

TABLE 4-39

ATLANTIC STURGEON IMPINGED ON INTAKE SCREENS AT HUDSON RIVER POWER PLANTS

YEAR	POWER PLANT: BOWLINE POINT		LOVETT		INDIAN POINT	ROSETON		DANSKAMMER POINT		TOTAL
	CAUGHT IN SAMPLES[a]	ESTIMATED TOTALS[b]	CAUGHT IN SAMPLES[a]	ESTIMATED TOTALS[b]	CAUGHT IN SAMPLES[a]	CAUGHT IN SAMPLES[a]	ESTIMATED TOTALS[b]	CAUGHT IN SAMPLES[a]	ESTIMATED TOTALS[b]	
1972	-	-	-	-	35[d]	-	-	-	-	111[e]
1973	14	127	8	107	48	3	11	7	84	377
1974	6	43	9	75	135	4	14	5	53	320
1975	18	115	3	21	123	9	80	1	9	348
1976	5	26	1	6	17	2	15	1	9	73
1977	3	11	0	0	197	11	59	6	35	302
1978	4	-	-	-	-	1[f]	-	-	-	

- Information not available.

[a] Actual count of fish impinged during sampling periods

[b] Consolidated Edison estimated of total impinged sturgeon, obtained from extrapolation of total sample water volumes.

[c] Sum of actual count at Indian Point and estimated total numbers at other plants unless otherwise noted.

[d] Does not include any Atlantic sturgeon impinged before June 1, 1972

[e] From Hoff et al.(1979) as cited in Dovel (1979)

[f] As of 5 June, 1978

Source: Dovel, 1979

power plants now appear to affect only a small number of sturgeon. However, if sturgeon populations begin to recover, as Dovel (1979) maintains is possible, power plant impacts on sturgeon may become more substantial.

IMPACTS ON HUMAN RESOURCES

4.247 The principal function served by the Bowline Point Generating Station and other generating stations on the Hudson River, in relation to the human resources of the study area, is the supply of electrical energy. The station contributes to the area's economy and the welfare of its inhabitants by providing energy to meet the needs of residential consumers, industry, commerce and the public sector.

4.248 As part of the integrated network of the New York Power Pool, the Bowline Point station and the other power plants on the Hudson River estuary are operated to yield the highest degree of reliability and economy in the supply of electrical energy. Contractual agreements among member companies of the pool provide for coordination in the participants' electric systems and a sharing in the benefits that can be realized through such coordination. Electrical energy in bulk is transmitted routinely into, through, and out of the study area (New York Power Pool, 1976).* The benefits associated with electrical energy generated within the area, therefore, may be distributed well beyond its boundaries and, conversely, the area's residents could derive benefits from electrical energy generated in power plants located outside of the area.

4.249 The adverse impacts resulting from the construction and operation of power plants, on the other hand, tend to be more localized. Notable exceptions are such phenomena as the widespread transport of pollutants and the propagation of ecological effects, the implications of which may be far reaching. With these exceptions, it appears that the environmental costs of generating electrical energy are borne disproportionately by a segment of the population generally smaller than the segment deriving the associated benefits.

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*Full economic integration in the day-to-day operations of the New York Power Pool was realized in 1977. Energy to meet the needs of all customers of the member companies is generated in the most economical manner, and account is taken of the efficiency of the generating units within the system, the cost of fuels, and the availability of individual units as well as transmission, reliability and other technical constraints.

4.250 The notion of arriving at an equitable distribution of benefits and costs has attracted considerable attention, particularly in the case of power plants on the Hudson River estuary (for example, Mid-Hudson Patterns for Progress, 1976). The question of equity is recognized here as an important element in gauging the socioeconomic impacts associated with the operation of the Bowline Point Generating Station and other plants on the Hudson River. The related issues, hwoever, are controversial and remain largely unresolved. Accordingly, the approach followed in the present analysis focuses on the socioeconomic effects that are evident and potential effects that may be anticipated from the continued operation of the Bowline Point and Roseton stations. No attempt is made to subdivide the study area or to consider whether the study area as a whole is a net importer or exporter of electrical energy.

Visual Impacts

4.251 The Bowline Point Station appears massive against the background of the Villages of Haverstraw and West Haverstraw. Plant structures are extremely conspicuous from many residentail and commercial sections in the vicinity. The central building, stacks and fuel loading facility are particularly dominant features in the view from much of the riverfront and the east bank of the Hudson River.

4.252 In its setting, the Bowline Point Generating Station is a severe visual intrusion. The intensity of the associated impact is attributed mostly to the scale of the plant structures and the sensitivity of the affected area. Concealment of the plant is virtually impossible due to the local terrain, and the height and starkness of the structures generally compound the effect of bulk. Although the plant is sited in an industrial zone, it is distinguishable from neighboring residential developments and the scenic shoreline of the Hudson River. In addition, a negative value is generally ascribed to large functional buildings where they dominate the visual elements of their immediate environs.

4.253 Reservations concerning the architectural merits of the power plant structures have been expressed by the Hudson River Valley Planning Commission. Despite such shortcomings, however, the Bowline Point station presents the functional aspect of a modern, oil-fired power plant. Equipment, piping and cables are, to a large extent, enclosed or buried. An earthen berm surrounding the fuel oil storage area provides partial concealment of the tanks and related equipment. The exterior color of the main buildings and other major components of the plant have been selected to reduce the visibility of the structures. The plant area has generally benefited from the site preparation work involving the removal of discarded automobiles and other trash, improved drainage and vegetation and pest control measures. Landscaping, particularly in the area of the Bowline Point recreational facility, is adequate.

4.254 Certain factors tend to mitigate the visual impact of the Bowline Point station. These stem from the long history of development on the Hudson River and the numerous visible signs of industrial activity along its shores. Manufacturing plants, quarries, fuel storage facilities, and transportation terminals are commonplace. Major electrical generating facilities sited upstream of Bowline Point include the Lovett Generating Station, in operation since 1949; the Indian Point Station, where construction of the first unit began in 1956; and the Danskammer Generating Station, in operation since 1951. The Bowline Point Station is not a unique installation along the reach of the Hudson River between the Tappan Zee and Mid-Hudson Bridges, but, together with the Roseton and the later units at Indian Point, represent successive additions of relatively familiar features in the visual setting. To a limited extent, the incongruity of the Bowline Point Station at its present location is diminished by the presence of similar facilities within the area.

4.255 The visual dominance of the Bowline Point Station will be aggravated by the installation of a closed-cycle cooling system at the station. An artist's impression, shown in Figure 4-10 illustrates the effect of adding massive natural draft cooling+towers, tentatively identified by Orange and Rockland as the preferred closed-cycle cooling alternative. The towers would be 393 feet in height, 315 feet in base diameter (Orange and Rockland, 1977). Visible plumes from the towers, expected to occur frequently during operation, could add moderately to the visual intrusion (U.S. Nuclear Regulatory Commission, 1976). Cooling systems with mechanically assisted towers might be applied at the Bowline Point station as practical alternatives. These structures are not as high as the equivalent natural draft towers and dimensions are generally more proportionate to the existing structures. Visible plumes generated by mechanical draft towers would remain closer to ground level. An alternative that might prove to be technically feasible (Section 6) is to provide cooling for the station with a single natural draft or mechanical draft tower. This would require a cooling tower with a base area roughly double that of the duel towers discussed above. In the case of natural draft towers, a comminserate increase in height would be needed to generate an adequate flow of air; in the case of a mechanical draft tower, a single tower effectively represents a reconfiguration of the modules or "cells" making up the duel tower system. The potential visual impacts of cooling towers, if these are installed at Indian Point Units 2 and 3, have been studies extensively and are considered by the U.S. Nuclear Regulatory Commission to be

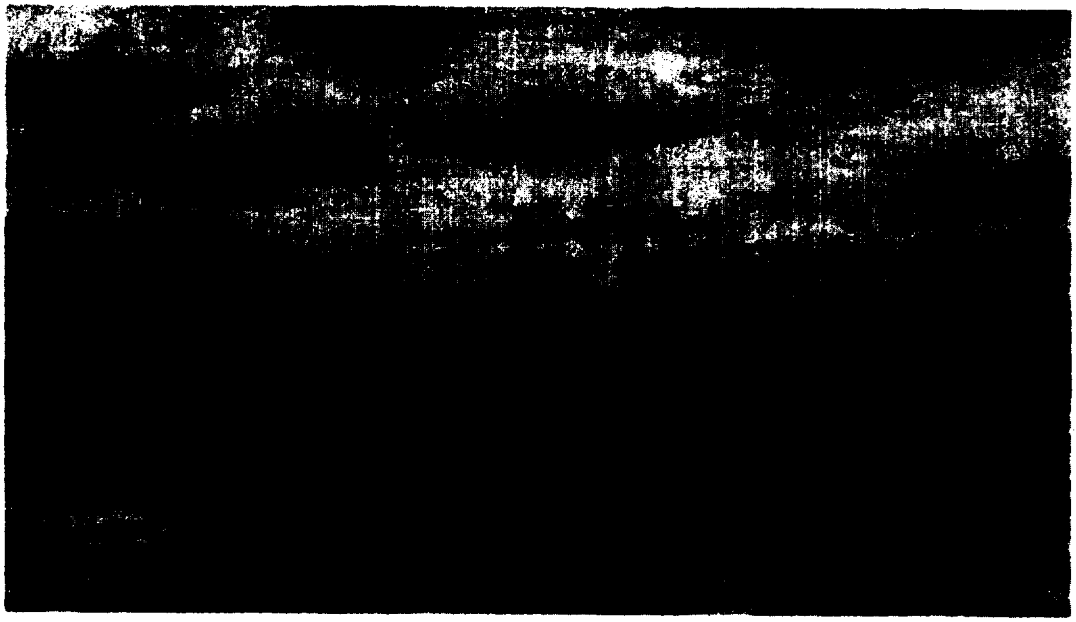

FIGURE 4-10
ARTIST'S IMPRESSION OF THE BOWLINE POINT GENERATING STATION
WITH AND WITHOUT COOLING TOWERS

the "most socially and economically consequential of the various possible environmental impacts" associated with closed-cycle cooling at the Indian Point units (U.S. Nuclear Regulatory Commission, 1976). Considerable opposition to cooling towers at the Indian Point units has been expressed by the Village of Buchanan, the City of Peekskill and others (U.S. Nuclear Regulatory Commission, 1976).

Noise Impacts

4.256 In the initial months of operation, mechanical noise from large fans used at the Bowline Point Station to induce the flow of air and combustion gases through the boiler and stacks, was sufficient to elicit complaints from local residents in the immediate vicinity. Orange and Rockland installed the appropriate silencing equipment and eliminated the source of annoyance. There have been no subsequent complaints concerning noise from the power plant (Rotella, 1977).

4.257 During construction of the cooling towers, noise levels will increase due to fabrication and removal of concrete forms, and the use of cranes, concrete trucks, and excavation equipment. However, the noise will occur only during working hours and will be temporary.

4.258 The level of noise generated by the station may be expected to rise as a result of the operation of a closed-cycle cooling system. Operational noise level in large natural draft towers is generally in the range of 80 to 90 dB(A) (Edmonds et al., 1974). The noise is associated primarily with the falling of water through the towers and the noise generated by the flow of large volumes of air (U.S. Environmental Protection Agency, 1974). Beyond a very short distance from the towers, the sound is "white" or broad spectrum and free of impulses or prominent discrete tone characteristics. During periods of continuous operation, the sound remains constant in level and blends readily in the audible background (U.S. Nuclear Regulatory Commission, 1976).

4.259 Propagation of the sound is affected by many factors, including atmospheric absorption, topography, barriers and vegetative cover. Accordingly, a site-specific study is required to establish the precise sound levels that would be generated by cooling towers serving the Bowline Point station. No analysis of the noise aspect of closed-cycle cooling at the station has been carried out to date (Orange and Rockland, 1976). Drawing a parallel with the natural draft cooling tower proposed for Unit 2 of the Indian Point Station (U.S. Nuclear Regulatory Commission, 1976), it is estimated, for present purposes, that noise increments of the order of 0.5 to 1.5 dB in A-weighted day-night equivalent sound levels (L_{DN}) might be experienced in the residential areas surrounding the Bowline Point station. Increases of this magnitude are considered unlikely to cause reaction from the communities in the vicinity of Indian Point (U.S. Nuclear Regulatory Commission, 1976). The situation may differ somewhat in Haverstraw because of the proximity of neighborhoods to the order of 40 dBA (Orange and Rockland, 1972) characterizing a quiet residential area (New York State Department of Environmental Conservation, 1974).

Public Safety

4.260 The operating plant and storage of fuel oil at the Bowline Point station constitute a finite risk of explosion and fire. However, the likelihood of damage occurring beyond the station boundaries as a result of an accident at the plant is remote. All major equipment installed at the Bowline Point station is of standard design, with a record of safety and reliability established by extensive application in generating stations throughout the country. The plant is operated in accordance with procedures adopted widely by the utility industry. Fire protection systems in the main plant area and fuel storage facility are designed to provide adequate capability to extinguish major fires and prevent their spreading. An interconnection between the two systems ensures added backup capability in the event of a serious emergency (Orange and Rockland, 1971). The associated hazard to public safety is considered to be at a generally acceptable level.

4.261 Fuel oil is delivered to the site by barge or tankers. River traffic to and from the plant is readily accommodated and poses no undue hazard to waterborne commerce or pleasure boating. Occasional deliveries of equipment and materials to the power plant constitute a minor demand on railroad and transportation systems serving the area. The power plant is staffed continuously with three work shifts per day. At times of shift changes, automobile traffic in the vicinity of the plants increases but causes no appreciable congestion or unusual hazard on local roads (Rotella, 1976).

Employment and Local Economy

4.262 The Bowline Point Generating Station provides employment for a work force of 100 persons that includes plant operators, maintenance staff and administrative personnel (Chapter 3). Employees reside in a wide area surrounding the station and commute to work (established during site visit on 3 and 4 November 1976).

4.263 The owners of the Bowline Point station make annual tax payments amounting to approximately $8 million to the Town of Haverstraw and the Village of Haverstraw. Details of these payments are as follows:

	TOWN OF HAVERSTRAW		VILLAGE OF HAVERSTRAW
YEAR	STATE AND COUNTY	SCHOOL TAX	
1975	$2,730,000	$4,700,000	$175,000
1976	$3,028,000	$4,900,000	$176,000
1977	$3,003,000	Not Available	

Information supplied by Orange and Rockland, Utilities, Inc..

4.264 The service requirements of the operating station are readily accommodated by the local infrastructure (Rotella, 1976; 1977). Water is supplied to the station by the municipal system at the rate of 275,000 gallons per day. Approximately 19,000 gallons per day are returned as sanitary and miscellaneous wastes (Chapter 1 and 4) for treatment by the sewage treatment plant. The design capacity of the treatment facility is 4 million gallons per day and is currently adequate (Rotella, 1976; 1977). Small quantities of solid wastes are generated by the operation of the station. Oily wastes and chemical wastes from certain maintenance cleaning procedures (Chapter 4) are disposed of through commercial contractors.

4.265 Construction of cooling towers, if these are installed at the Bowline Point station, is expected to lead to an increase in local traffic and employment. The construction period would extend over two years (Orange and Rockland, December 1974a) and involve an average of 125 workers per year. Orange and Rockland estimates that approximately one-third of the work force would be composed of local residents, the remainder being drawn from the surrounding area. It appears unlikely that the construction work would attract a significant number of people to establish a permanent residence in the vicinity of the power plant. Cooling towers would add an estimated $70 million in capital costs to the value of the station, leading to an increase in local property taxes.

Historical Resources

4.266 On the basis of criteria* developed by the U.S. Department of the Interior to determine the effect of a Federal, Federally-assisted or Federally-licensed undertaking on properties included in or eligible for inclusion in the National Register of Historic Places (39 FR, No. 18), the Bowline Point and other generating stations could have adverse impacts on certain historic properties listed in Table 2-17 by virtue of the visibility of the stations. It is impossible to estimate quantitatively in the severity of these impacts. The Bowline Point station is highly visible and dominant in its setting. Certain factors, discussed above, however, may tend to mitigate the visual effects of the station.

4.267 As discussed earlier in Chapter 4, operation of evaporative closed-cycle cooling systems at the Bowline Point and Roseton generating stations gives rise to the deposition of salt and a remote possibility of generating acidic mists. There is a small attendant risk of causing damage to properties, including those of historic interest in the immediate vicinity of the Bowline Point and Roseton generating stations (Chapter 2). As discussed in detail in Chapter 6, the retrofitting of a closed cycle cooling system at each of these stations would entail a reduction in generating capacity and overall efficiency of the station. In addition to the initial capital cost of the closed-cycle cooling system, there are both economic and energy penalties associated with this loss in efficiency. Further, the operation of an evaporative cooling system would give rise to an increased consumptive use of water, estimated in an earlier part of the present analysis to be of the order of 1.5 to 2 times the current level of consumption.

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*The criteria are:

"Generally, adverse effects occur under conditions which include but are not limited to:
(a) Destruction or alteration of all or part of a property;
(b) Isolation from or alteration of its surrounding environment;
(c) Introduction of visual, audible, or atmospheric elements that are out of character with the property or alter its setting;
(d) Transfer or sale of a Federally-owned property without adequate conditions or restrictions regarding preservation, maintenance, or use; and
(e) Neglect of a property resulting in its deterioration or destruction."

CHAPTER 5
ADVERSE IMPACTS THAT CANNOT BE AVOIDED

5.01 The principal unavoidable impacts associated with the operation of the Bowline Point and Roseton Generating Stations are those occasioned by the physical presence of the power plants (visibility and occupation of land), the release of combustion products and the rejection of waste heat. Both stations are in commercial operation and the unavoidable effects experienced during the construction phase of the projects have completely subsided. There are no indications of tangible, deleterious effects that have persisted from the influx of a large labor force and material, the generation of noise and dust, site clearing, grading, filling, excavation and other activities likely to lead to erosion and turbidity and siltation in nearby surface waters. There are no reasons to believe that the construction of the Bowline Point and Roseton stations has affected groundwaters in their vicinities, or that groundwaters would be affected by the continued operation of these stations.

5.02 Both the Bowline Point and Roseton stations occupy relatively small tracts of land (245 acres and 133 acres, respectively) located at sites previously used by or in the vicinity of brickworks. In relation to the area of the lower Hudson River Valley, the land committed to the Bowline Point, Roseton, and other existing generating stations represents a small loss of wildlife habitat and agricultural and recreational resources. In view of previous uses of land at the Bowline Point and Roseton sites, no areas considered to be prime agricultural lands have been committed. The subject power plants, however, are highly visible from the river and riverfront. While there are no indications that the power plants have depressed property values in their immediate vicinities, the visibility of the stations could act as a deterrent to future developments or redevelopments in the area. Closed-cycle cooling systems at either or both stations would intensify their visual impact, particularly if evaporative natural draft cooling towers are installed.

5.03 Combustion products released by the Bowline Point and Roseton Generating Stations consist mostly of carbon dioxide and water vapor. There are no practical means of containing or controlling the release of carbon dioxide. The observed steady growth in the concentration of carbon dioxide in the atmosphere, attributed principally to the rapidly increasing use of fossil fuels since the turn of the century, is a factor linked closely to a potential inadvertent modification of climate on a global scale (see, for example, Machta and Telegadas, 1974). In this context, the contribution of the Bowline Point and Roseton stations to the carbon dioxide load on the atmosphere must be recognized as an unavoidable effect. No significant localized or regional modifications of the weather, however, are anticipated as a result of the release of carbon dioxide from fossil-fueled power plants on the Hudson River. Similarly, perturbations in temperature and the moisture content of the atmosphere, caused by the release of combustion products and the rejection of waste heat (even through evaporative cooling techniques), are not expected to give rise to any significant meteorological effects (Koenig and Bhumralkar, 1974).

5.04 Together with carbon dioxide and water vapor, the airborne emissions from the Bowline Point and Roseton stations contain measurable quantities of oxides of sulfur and nitrogen and particulates derived mainly from mineral matter present in the fuel oil. Emissions of these substances meet all New York State Standards applicable to stationary combustion installations (6NYCRR227). State ambient air quality standards currently in effect (6 NYCRR 257, effective 18 March 1977) are not being exceeded as a result of the operation of the Bowline Point Station. Central Hudson reports that since 1 August 1976 when the sulfur content of oil burned at the Danskammer power plant was reduced from 2.0 to 1.0 percent by weight, standards related to the concentration of sulfur dioxide are no longer being exceeded in the vicinity of the Roseton station. The Federal secondary standard for ambient concentrations of particulate matter (40 CFR 50.5) is being exceeded occasionally in the vicinity of the Roseton Station. There are no indications of significant interactions of a cumulative nature among the airborne emissions from fossil fueled power stations on the Hudson River estuary. These emissions, nonetheless, contribute to the general level of airborne contaminants in the lower Hudson River Valley.

5.05 Emissions of sulfur and nitrogen compounds will contribute to the overall regional concentrations of sulfate and nitrate aerosols and the attendant hazards of acid precipitation in the northeastern United States (see, for example, U.S. Department of Agriculture, 1976). The interaction of stack gases with atmospheric moisture could, in principle, lead to the formation of acidic mists. This phenomenon could become more prevalent if evaporative cooling systems are installed at the Bowline Point and Roseton generating stations and if the fumes from the stack and cooling systems interact at either station. Experience to date, however, has not shown that such interactions lead to appreciable problems at ground level.

5.06 In addition to the gross contaminants, certain compounds and elements are released in relatively small or trace quantities with the combustion gases. Among these are carbon monoxide, hydrocarbons and aldehydes and a number of trace metals and their derivatives. Trace elements contained in crude oil, other than sulfur and those normally considered to be constituents of mineral matter (silicon, aluminum, iron, titanium, calcium and the alkali metals), include vanadium, nickel, zinc and copper in concentrations that vary, especially with the source of oil (Babcock and Wilcox, 1972). The distillation of crude oil causes virtually all of the metallic compounds and a large part of the sulfur compounds to concentrate in the residue of the process, that is, in residual fuel oil (Babcock and Wilcox, 1972) of the type burned at the Bowline Point and Roseton stations.

5.07 Relatively little is known about the mobilization and ultimate fate of the trace constituents of fuel oil burned in power plants. Recent investigations have dealt with coal fired plants and demonstrated that the disposition of trace elements and compounds is determined largely by their volatility (Natush et al., 1974; Kaakinen et al., 1975; Klein et al., 1975). The most volatile substances probably are discharged in the gaseous phase. Others, including zinc, tend to concentrate in the fly ash discharged from the stack, while the least volatile substances are retained within the boilers. It is unclear at present whether vanadium and nickel exhibit the characteristics of the least volatile substances or whether there is a certain tendency for these substances to escape. Rough parallels may be drawn in the case of fuel oil combustion and it is expected that at least some of the trace constituents of the fuel are released. However, successful efforts at recovering vanadium commercially from slag, bottom ash and boiler deposits at the Albany station and other oil-fueled stations (Electrical World, 1977; O'Neal, 1977; Lalena, 1977) have shown that a substantial portion of the vanadium present in the fuel oil is retained within the combustion system. The behavior of copper is unknown.

5.08 Considerable attention is focused on the trace contaminants from the combustion of fossil fuels because of the carcinogenicity or suspected carcinogenicity of several of the elements and compounds involved (Kornreich, 1976). Accordingly, the release of these substances from the Bowline Point, Roseton and other fossil fueled stations on the Hudson River estuary, is regarded as a contributory risk to public health, presently unavoidable and of unknown severity.

5.09 The withdrawal of water from the Hudson River to provide the means of rejecting waste heat and satisfy other service requirements gives rise to certain unavoidable effects. Under present conditions, the withdrawal of water by power plants on the Hudson River estuary results in the destruction of aquatic organisms by entrainment and impingement. Estimates of the extent of the damage are still the subject of serious scientific debate. Research has been focused principally on the effect that the continued operation of existing power plants with once through cooling would have on the population of striped bass in the Hudson River.

5.10 Present estimates of the Utilities are that the striped bass population would be reduced on the average from 8 to 11 percent with continued operation of existing power plants with once-through cooling systems on the Hudson River. White perch population could be reduced up to 14 percent. Data are not available on possible losses of other species. Staff of the U.S. Environmental Protection Agency believe that estimates are unreliable and that fish population could be affected to a much larger extent. The installation of evaporative closed-cycle cooling systems at all the eligible power plants on the river would reduce but not entirely eliminate the destruction of aquatic organisms. Power plants not subject to the potential requirements to install closed-cycle cooling systems would continue to operate with open-cycle cooling. Moreover, some withdrawal of water would be needed at the power plants with closed-cycle cooling to compensate for operational losses of water. Notwithstanding the unresolved issues, it is evident that some destruction of aquatic organisms is an unavoidable consequence of the operation of the power plants, even with the installation of closed-cycle cooling systems. On the other hand, there is sufficient evidence to suggest that this destruction could be reduced from present levels by means other than cooling towers. In the case of the Bowline Point and Roseton stations, the water intake structures and screening mechanisms could be modified to take advantage of recent developments in techniques aimed at reducing damage to fish as a result of impingement (Chapter 6). A second approach is that of coordinating the operation of power plants on the river and elsewhere in New York State so as to avoid affecting critical areas at critical times (Chapter 6). It is impossible, at present, to predict how successful, if at all, such measures would prove to be.

5.11 Other potential impacts associated with the operation of the Bowline Point and Roseton Generating Stations are minimized through the application of appropriate mitigating measures. The release of waterborne contaminants (except heat) reflects the application of the best available control technology economically achievable, in the context of Section 301 of the Federal Water Pollution Control Act of 1972 (PL 92-500), at both power plants. The attendant impacts on the waters of the Hudson River are small. Small quantities of solid waste, such as ash, spent resins and miscellaneous trash, as well as waste solutions generated by cleaning and other maintenance operations, are disposed of by commercial contractors. Noise from the operating stations is abated by the appropriate suppression equipment to levels sufficiently low to be acceptable to resident communities in the vicinity of the power stations.

5.12 Fuel oil is delivered to both stations by barge or tanker, and added traffic on the Hudson River poses the risk of oil spillage and an additional hazard to commercial and recreational navigation. Both Orange and Rockland and Central Hudson have developed spill prevention control and countermeasure plans (Orange and Rockland, 1974; Central Hudson, 1974) covering these companies' facilities on the Hudson River and incorporating all applicable regulations of the U.S. Coast Guard and U.S. Environmental Protection Agency (40 CFR 112). These plans set forth inspection and operating procedures related to the receiving, storage and transfer of fuel oil and countermeasures and reporting procedures to be followed in the event of spills. The procedures combine regulations and sound engineering practices to ensure that the risk of discharging oil in harmful quantities is minimized.

5.13 Notwithstanding the mitigating measures that have been taken, residual effects and risks persist. In many instances, these could be reduced further through the application of technological controls, procedures and other available measures. The exercise of additional control, however, is presently not considered to be warranted since the health, safety and welfare of the public are not unduly comprimised.

5.14 The use of evaporative closed-cycle cooling introduces a possibility, albeit small, of ground level fogging and icing, air increase in the formation of acidic mists, generation of noise, and deposition of salt (Chapter 6). The phenomenon of drift, which can be reduced to low levels but not entirely eliminated, is responsible for the spread of dissolved and suspended substances contained in the source of cooling water. Damage to vegetation from the deposition of salt is a possibility. Also noteworthy is the presence of polychlorinated biphenyl compounds predominantly in the sediment of the Hudson River. Although the concentration of these substances in solution or suspension may be extremely low, their mobility and high toxicity to humans and other animals are factors that warrant consideration as elements of risk associated with the long-term operation of the power plants with closed-cycle cooling.

CHAPTER 6

ALTERNATIVE ACTIONS

6.01 The District has considered several alternative actions related to its permit authorizing construction in the navigable waters of the Hudson River of water intake structures forming part of the Bowline Point Generating Stations. The alternatives available to the District are to (1) retain unaltered the present permit and related conditions, (2) modify the permit through the imposition of additional conditions, (3) suspend the permit, or (4) revoke the permit.

6.02 Retention of the present permit would allow Orange and Rockland to operate the Bowline Point station without additional regulatory restrictions imposed by the District. Operation could continue throughout the operational life of the plant with the existing once-through cooling system, unless a closed-cycle cooling system is installed at the station in accordance with the current requirements of the U.S. Environmental Protection Agency. Therefore, the District has analyzed the impacts associated with the operation of the Bowline Point station under conditions of both open-cycle and closed-cycle cooling (Section 4). The owners of the Bowline Point station are contesting the need for closed-cycle cooling and adjudicatory hearings on the matter are being held before the U.S. Environmental Protection Agency (Appendix B).

6.03 The imposition of special conditions, in addition to those currently specified in the subject permit, has been considered as the second possible course of action. These conditions could apply to the operation of Bowline Point station with once-through or with a closed-cycle cooling. Suspension of the District's permit, a third possibility would require the Bowline Point station to be shut down until a closed-cycle cooling system is installed. The fourth alternative, revocation of the permit, would cause the permanent abandonment of the plant.

6.04 The same alternatives are available to the District in the case of the permit issued in connection with the Roseton Generating Station. The U.S. Environmental Protection Agency requires that a closed-cycle cooling system be installed at the Roseton station and the owners are contesting this requirement. Accordingly, the District has evaluated the impacts associated with the various alternative actions applied to the Roseton station in the context of continued operation with open-cycle and closed-cycle cooling.

ALTERNATIVE ACTIONS RELATED TO THE BOWLINE POINT STATION

6.05 The current National Pollutant Discharge Elimination System permit governing waterborne discharges from the Bowline Point station requires that operational levels of closed-cycle cooling be attained by 1 July 1981. A final selection of the type of closed-cycle system to be installed at the station, should the requirement for closed cycle cooling remain in effect, has not been made to date. Orange and Rockland has identified evaporative, natural draft cooling towers as the preferred closed-cycle cooling option. A preliminary study (Orange and Rockland, 1974) has demonstrated the engineering feasibility of installing this type of cooling system at the Bowline Point station and established a first estimate of the monetary costs involved.

Retention of Present Permit

6.06 The principal advantages of retaining the present permit stem from the unencumbered operation of the facility and, if a closed-cycle cooling is ultimately installed, an orderly transition from operation with open-cycle to closed-cycle cooling. While operating without additional restrictions, the Bowline Point station would continue to generate electrical energy to meet the needs of customers served by Orange and Rockland, and contribute to the reliability and economy of operation of the New York Power Pool (Appendix C). A closed-cycle cooling system, if retrofitted in accordance with the stipulations of the current National Pollutant Discharge Elimination System permit, would be brought into operation within a period of approximately 4 1/2 years, allowing sufficient time to draw up the detailed specifications and design of the system, secure the necessary authorizations, complete construction and testing and, finally, tie in the cooling system to the rest of the plant. At the time of the Draft Environmental Statement, a preliminary schedule (Orange and Rockland, 1974) showed that construction would proceed over subsequent three years until both towers are completed and equipped with the necessary internal components. Testing and tie-in would extend over two months.

6.07 Retention of the permit implies that the impacts associated with the operation of the Bowline Point station on open-cycle cooling (Chapter 4) would continue to prevail, either for an interim period or until the power plant is retired, depending on the outcome of hearings before the U.S. Environmental Protection Agency. The principal intent of installing closed-cycle cooling at the Bowline Point station is to reduce the rate of intake of cooling water to 2 or 3 percent of that needed for once-through cooling and, thereby, reduce damage caused by entrainment and impingement of striped bass and other aquatic organisms.

6.08 This reduction could be effected by installing one of several alternative closed-cycle cooling systems, each involving a distinctive set of environmental tradeoffs relating to land and water use, the release of water vapor and spray to the atmosphere, the generation of noise, the visual features of the cooling system, and monetary costs. In the analysis of impacts documented so far (Chapter 4), closed-cycle cooling has been treated generically, that is, without consideration of a specific type of cooling system. Exceptions have been made where impacts cannot be assessed without reference to a particular type of system. In such instances, the impacts described are those related to evaporative natural draft towers. The analysis is extended here to consider all of the practical cooling alternatives that might be applied at the Bowline Point station, thereby assessing a range of possible implications associated with the retention of the subject permit.

Cooling Alternatives*

6.09 The once-through or open-cycle technique of rejecting waste heat from an operating steam electric power plant involves a constant withdrawal of cooling water from a suitable source, circulation of the water through the plant condensers and discharge of the heated stream to receiving waters. In a closed-cycle cooling system, heated water from the condenser is passed through a cooling device and is next recycled to the condenser. If cooling is effected to a substantial degree (25 to 75 percent) through evaporation of a portion of the circulating water, the device is said to be evaporative. In such a system, the balance of the waste heat is rejected through the transfer of heat to air. Dry cooling operates entirely on this latter principle. Heat is rejected without any direct contact between air and water, that is, without the assistance of evaporation or the attendant loss of water. Wet-and-dry systems combine the features of evaporative and dry cooling.

6.10 Evaporative cooling systems require a constant supply of water to compensate for evaporative losses, drift (water droplets entrained by the flow of air or wind), and blowdown (a continuous or intermittent purge from the system to avoid an undue buildup of dissolved matter in the cooling water inventory). Although drift

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*A more detailed treatment of the technical characteristics of closed cycle cooling systems is given in Appendix D.

represents the least important component of water consumption, considerable attention is devoted to its associated hazards of depositing salts and other substances potentially harmful to health, vegetation, and property.

6.11 The two broad categories of evaporative cooling systems are cooling ponds and cooling towers. The term cooling pond* designates a manmade impoundment constructed to provide cooling water for steam electric plants or other industrial facilities. The impoundment may take one of several forms, the simplest being a large reservoir that acts as source and sink for a once-through cooling system. Other forms include cooling canals and smaller reservoirs equipped with powered spray devices. Cooling towers are available as natural draft towers, in which the flow of air is induced through the density gradient (temperature and humidity) within the tower, and mechanical draft towers, where the flow of air is either induced or forced mechanically. A number of combinations or hybrid systems represent possibilities that may be advantageous in certain specific applications. These include the wet-and-dry concept mentioned previously and natural draft towers with mechanical assistance. Other cooling systems are designed to reject part of the imposed heat load before a discharge is made to receiving waters. While such systems may be useful where the thermal component of the discharge is an overriding factor, they are not considered further in the present analysis, since the intake rate of cooling water is not reduced by the application of any of these systems.

6.12 The economic penalties of operating a power plant with closed-cycle cooling result from the increase in the temperature of the cooling water at the condenser inlet over temperatures that generally prevail with once-through cooling (Appendix D). There is a corresponding increase in the temperature of the condensate and, consequently, an increase in the back pressure at the steam turbine exhaust. This gives rise to a loss of electrical generating capacity and a decrease in the overall thermal efficiency of the plant. In addition, more energy is expended in circulating the water through a closed-cycle system than is generally the case with once-through cooling. Further losses in electrical output are incurred where power is needed to drive mechanical fans or spray devices.

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*The term "cooling lake" is used occasionally to differentiate an impoundment which impedes the flow of a navigable stream from a "cooling pond" which may draw water from or discharge water to a navigable stream but does not otherwise impede its flow (U.S. Environmental Protection Agency, 1974).

6.13 The principal ecological advantage of the use of closed-cycle cooling over once-through cooling would be to reduce the rate of entrainment and impingement of aquatic organisms (Chapter 4). It may be well to note, however, that the probability of survival of an organism entrainment into a closed-cycle cooling system with cooling towers is reduced practically to zero.

6.14 The principal ecological disadvantage the use of evaporative closed-cycle cooling would be the potential for damage to vegetation from salt drift (Chapter 4). Other disadvantages include the visibility of cooling towers and their plumes as well as the economic and energy penalities associated with these systems.

Closed Cycle Cooling at the Bowline Point Generating Station

6.15 The design specifications underlying the preliminary study of closed-cycle cooling at the Bowline Point Generating Station (Orange and Rockland, 1974) provide the basis for the comparative analysis of cooling alternatives presented here. Each closed-cycle cooling system is sized to reject the current waste heat load and maintain the flow of water through the plant condenser at the current rate. Accordingly, the temperature rise across the condensers would remain unchanged.

6.16 Pertinent design characteristics and conditions applicable to closed-cycle cooling at the Bowline Point station are:

PARAMETER	VALUE
Heat rejection per unit, billion BTU per hour	2.82
Circulating water flow, gallons per minute	375,620
Cooling range, °F	15
Approach, °F	14.9
Design dry bulb temperature, °F	86
Design wet bulb temperature, °F	74

The design temperature of the cooling water at the condenser inlet would increase from the present value of 70 to 89 F., with a corresponding increase in design turbine back pressure from the current 2 inches of mercury absolute to 3 inches of mercury absolute.

6.17 The existing intake structure and service water system would be retained. New pumps would be installed to supply service water at the rate of 8,000 gallons per minute to each of the generating units. Water discharged from the service water system would be made available as makeup for evaporative closed-cycle cooling at a rate essentially equal to that of the intake. It may be well to note that there are design features that apply to the average performance of the system over a given year. Variations can be anticipated throughout the year, with the most efficient operation, of the system expected in cool, dry weather and the least efficient in warm, moist weather. For example, translating the increase in back pressure into a loss of generating capacity, a reduction of the order of 3 percent might be the average for a year's operation but the peak reduction in summer might amount to 5 percent. Further, a design based on these figures is somewhat conservative since the actual heat rejection from each of the Units presently amounts to 2.14 billion BTU per hour (Chapter 1).

Evaporative Natural Draft Cooling Towers

6.18 Rejection of the waste heat load from the Bowline Point Generating Station through evaporative natural draft cooling towers would require two towers, each 393 feet high with a base diameter of 315 feet (Orange and Rockland, 1977).

6.19 Evaporative water losses from each of the cooling towers, estimated on the basis of 0.08 percent of the circulating water rates per degree F of cooling range (Marley, 1969), would average 4,500 gallons per minute (6.5 million gallons per day). Drift losses with standard drift eliminators would amount to 0.05 percent of the circulating water rate or 200 gallons per minute (0.3 million gallons per day). The installation of specially designed drift eliminators could reduce drift to the range of 0.002 to 0.02 percent of the circulating water rate (U.S. Environmental Protection Agency, 1974) and give rise to a corresponding loss in the cooling effectiveness of the tower. With a makeup rate of 8,000 gallons per minute per tower, blowdown could be maintained at an average value of 3,300 gallons per minute or 0.9 percent of the circulating water rate. Under these conditions, the equilibrium concentration of dissolved solids in the cooling water inventory would be a factor of 2.2 higher than the concentration of these substances in the Hudson River. Blowdown taken from the cold side of each tower at the rate of 3,300 gallons per minute and at design conditions of 19 F above ambient river temperature represents a thermal discharge of 31.4 million BTU per hour.

6.20 Other properties of the liquid discharge from the cooling towers and chlorination schedules would have to meet standards characterizing the application of "best available technology economically achievable" (40 CRF 423.13) Among these, the limitations on free available chlorine in the cooling tower blowdown (0.5 milligrams per liter maximum concentration and 0.2 milligrams per liter average daily concentration over 30 consecutive days) make it necessary to install a dechlorination treatment system. In its preliminary investigations, Orange and Rockland has considered a sulfur dioxide chemical feed system to reduce free available chlorine to levels at or below those acceptable to the U.S. Environmental Protection Agency.

6.21 The increased back pressure at the turbine exhaust resulting from the application of evaporative natural draft cooling gives rise to an estimated loss of 6 megawatts of generating capacity per unit at design conditions. Additionally, 3.5 megawatts per unit are needed to meet the increased requirement in power to circulate the cooling water. The total derating of the plant at design conditions amounts to 19 megawatts, representing approximately 1.6 percent of the station's net capability. The total penalty in generating efficiency is 145 BTU per kilowatt-hour, increasing the net plant heat rate from the current value of 9,135 BTU per kilowatt-hour to 9,250 BTU per kilowatt-hour.

6.22 Atmospheric Effects. Theoretical considerations relating to the release of warm, moist air from the cooling towers indicate that a visible plume (or artificial cloud) would be formed under the appropriate meteorological conditions and that a potential exists for creating fog and icing at ground level and causing alterations in local meteorology. Predictive analyses of plume formation by a proposed natural draft tower at the Indian Point site, as well as extensive observations of cooling towers both in the U.S. and abroad (U.S. Nuclear Regulatory Commission, 1976), suggest that plumes from the towers at the Bowline Point station would usually be visible during unit operation. The shape, rise, length, and visibility of the plumes, however, would depend on prevailing meteorological conditions (air temperature, saturation deficit, windspeed and atmospheric stability). The smallest and shortest plumes would occur when the atmosphere is dry (relative humidity less than 85 percent, a condition that is expected to occur with a frequency of 95 percent in the vicinity of Indian Point). The largest and longest plumes would be formed when windspeeds are moderate and the atmosphere is very moist (relative humidity greater than 95 percent, windspeeds between 8 and 18 miles per hour, frequency of occurrence 3 percent). The plumes may then extend for several miles downwind and may merge with low clouds that are often associated with very moist conditions. Strong winds (greater than 19 miles per hour) inhibit the upward development of plumes and, in general, lead to plumes of lesser downwind extent than do moderate winds.

6.23 Because water vapor tends to condense more readily as temperature decreases, cooling tower plumes are most distinct and persistent during the coldest periods of each day and year (U.S. Nuclear Regulatory Commission, 1976). The visibility of a plume can be expected to depend on a number of variables and complex relationships involving the number and density of condensation droplets within the plume, the size distribution of droplets, sun angle and cloudy or hazy conditions. Under conditions of low visibility associated with a very moist atmosphere, it may become difficult to distinguish the cooling tower plume (U.S. Nuclear Regulatory Commission, 1976). On the other hand, the plume during clear, dry periods would be pronounced, especially when viewed at low sun angles with the sun behind the observer.

6.24 Observations at operating natural draft cooling towers show no instances of ground level fog and ice formation in areas of level terrain (U.S. Nuclear Regulatory Commission, 1976). There has been one reported case of a visible plume from a natural draft cooling tower reaching ground in mountainous terrain (Hosler, 1972). Predictive analyses of cooling tower plumes at Indian Point (U.S. Nuclear Regulatory Commission, 1975; 1976) show that ground level fogging might occur for 1 hour per year in addition to the average incidence of 79 hours per year of natural fog (defined as visibility of less than 1/4 mile at 33 feet above ground level). The potential for the formation of ice or frost at ground level or on structures in the path of the plume are negligible.

6.25 Only rough parallels can be drawn in the case of the Bowline Point Generating Station. A case-specific computer simulation would be needed to predict the risk of artifically producing these ground level phenomena, particularly in the area of the Hi Tor mountain to the southwest of the power plant. It may be anticipated, however, that the increase in the natural occurrence of fog and icing would be small, if at all discernible, in view of the relative infrequency of winds from the northeastern sector at the site and the absence of recorded observations of ground level and icing from operating natural draft cooling towers. No measurable increase in the incidence of fog and icing on level terrian around the site or on the river is expected. Studies relating to natural draft towers at Indian Point have shown that increases in ambient relative humidity as a result of moisture added to the atmosphere are inconsequential (U.S. Nuclear Regulatory Commission, 1976).

6.26 Under appropriate meteorological conditions, the rejected heat and water vapor could lead to the formation of cumulus clouds following the evaporation of the initial visible plume. This effect is most likely to occur where conditions are close to favorable for the natural formation of clouds and has been observed and recorded in a number of field studies (U.S. Nuclear Regulatory Commission, 1976). It is impossible to predict with any degree of certainty whether or where any detectable increase in precipitation might ensue. Cases of snowfall being induced by cooling towers have been reported (Kramer, 1976; Culkowski, 1962). The possibility exists that the amount of precipitation could be increased in a given locality as a result of moisture collected from the cooling tower plumes. A numerical model study of a specific application of a large natural draft tower in West Germany has shown that an increase of the order of 0.4 inches per year could be expected where the natural precipitation is 40 inches per year (Junod et al., 1974).

6.27 Noise. The operational noise level in large towers is generally in the range of 80 to 90 dBA (Edmonds et al., 1974). The noise from natural draft cooling towers is primarily that generated by falling water and the flow of large volumes of air through restricted spaces (U.S. Environmental Protection Agency, 1974). At short distances from the towers, the sound is "white" or broad spectrum sound, free of beats and impulses. During periods of continuous operation the sound remains constant in level and blends into background sounds (U.S. Nuclear Regulatory Commission, 1976). Propagation of the sound is affected by factors such as atmospheric absorption, topography, barriers, and vegetative cover.

6.28 A study of the offsite sound levels associated with the operation of closed-cycle cooling systems at Indian Point Unit 2 has shown that small increases in ambient noise can be expected in the vicinity of the plant, regardless of which type of cooling tower is selected (U.S. Nuclear Regulatory Commission, 1976). At 11 specific locations within 7,200 feet of the proposed tower (bordering the site, scattered in the Village of Buchanan and immediately across the Hudson River from Indian Point) the predicted increases rank from values below to values slightly above the threshold of detectability. The maximum increase in A-weighted day-night equivalent sound levels (L_{DN}) at any of the selected locations on the east bank of the river amounts to 0.5 to 1.5 dB for a natural draft cooling tower (the lower value applies to a cross flow tower and the higher value to a counterflow tower) and 1.4 dB for a conventional mechanical draft tower. The largest overall increase in LDN amounting to 3.2 dB, would occur on the west bank of the river with a mechanical draft tower. All of the predicted increases are below the value considered likely to cause a change in community reaction to the noise (U.S. Nuclear Regulatory Commission, 1976).

6.29 Costs. Preliminary estimates (Orange and Rockland, December, 1974) of the costs (in 1981 dollars) of retrofitting natural draft cooling towers to the Bowline Point station are:

Equipment and Installation--Capital Cost*

Pricing base, December 1974	$38,250,000
Construction management, home office cost and construction fees	4,775,000
Escalation to July 1981	19,585,000
Orange and Rockland in-house expenditures	750,000
Allowance for funds during construction	6,400,000
	$69,760,000
Say	$69,800,000

Capitalized Operational Cost

Cost of capability derating (19 megawatts total)	$12,635,000
Heat rate penalty	13,953,328
Incremental replacement capacity lost	8,530,000
Operation and maintenance	1,431,000
	$36,549,328
Say	$36,500,000
Total	$106,300,000

6.30 The capital cost of equipment and installation (with a pricing base of December 1974) includes the cost of the cooling tower structures ($19,940,000 in 1974 estimate), circulating water pumps, pumphouse, piping, electrical instrumentation, blowdown dechlorination system, miscellaneous equipment, and civil engineering work. Distributable costs ($1,360,000) are computed on the basis of 25 percent of direct labor cost and include the costs of maintenance of tools and equipment, material handling, other unallocatable field labor, general and final job cleanup and consumable supplies. In

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*Capital cost estimates revised to December 1976, cost estimates have been further revised and updated (Orange and Rockland, 1977b).

addition, an allowance of 5 percent of field cost is included in the distributable costs as the contractor's fee. Contingency ($4,990,000) is computed on the basis of .15 percent of the field cost.

6.31 Escalation in total field cost ($38,250,000) is computed at the rate of 15 percent for 1974, 10 percent for 1975, 8 percent for 1976 and 7 percent compounded yearly thereafter. Escalation in home office costs is computed at the rate of 10 percent for 1974, 10 percent for 1975 and 8 percent for 1976 and years thereafter.

6.32 The cost associated with a total capability derating of 19 megawatts is computed at a rate of $665 per kilowatt installed in 1981. The heat rate penalty is based on a total generation of 6.3 billion kilowatt hours per year (1,200 megawatts operating at a capacity factor of 0.6) and an increase in net plant heat rate of 145 BTU per kilowatt-hour. At a cost of fuel of $2.67 per million BTU ($16 per barrel of residual oil, 6 million BTU per barrel) the yearly penalty in 1981 dollars amounts to approximately $2,440,000. The corresponding capitalized cost at 17.5 percent carrying charge over a 30-year balance of life of the plant is approximately $14 million. The incremental replacement capacity cost allows for a planned outage of each unit for 2 months during the transition to closed-cycle cooling, leading to a loss of 1.05 million kilowatt-hours of generation. The purchase of an equivalent amount of energy at $0.0326 per kilowatt-hour would require $34,250,000. Credit for fuel not consumed during this period at $2.67 per million BTU amounts to $25,270,000 yielding a net value of $8,530,000 for the incremental replacement capacity cost.

6.33 Operation and maintenance cost is estimated at $0.21 per kilowatt of net capacity per year. The total cost for the plant amounts to $250,000 per year and represents a capitalized cost of $1,431,000.

Evaporative Mechanical Draft Cooling Towers

6.34 The waste heat load from the Bowline Point Generating Station could readily be accommodated by evaporative mechanical draft cooling towers of proven design and performance. Available variations include the conventional linear towers with forced or induced air flow and circular towers consisting of a single large cell or multiple cells (U.S. Environmental Protection Agency, 1974; U.S. Nuclear Regulatory Commission, 1976). In addition, a variety of designs of natural draft cooling towers with fan assistance have been developed, and a few such devices are in use in Europe (U.S. Nuclear Regulatory Commission, 1976). For present purposes, fan-assisted towers are considered together with mechanical draft towers, since the primary intent in resorting to power assistance is generally to reduce the bulk (and visibility) of the cooling tower structure to proportions more representative of mechanical rather than natural draft towers.

6.35 Assuming a loading of 6 gallons per minute per square foot of base area (compared to the 4 gallons per minute per square foot in the natural draft towers considered above), heat rejection from each Bowline Point unit would require a mechanical draft tower with 63,000 square feet of base, or nominal dimensions of 75 by 850 feet. The overall height of the tower would range from 75 feet, typical of most tower designs, to 200 feet for fan-assisted natural draft towers.

6.36 Mechanical towers designed to the reference specifications and conditions would consume water through evaporation at substantially the same rate as their natural draft counterparts. Drift rates are normally higher, typically by a factor of 2 or 3 (U.S. Nuclear Regulatory Commission, 1976) in mechanical draft towers but, through appropriate design of drift eliminators, can be reduced down to levels well below the 0.05 percent of throughput assumed in the present analysis. The characteristics of blowdown from mechanical draft would be essentially the same as those of blowdown from natural draft towers.

6.37 Atomospheric Effects. Atmospheric effects associated with the release of warm moist air and drift are potentially more pronounced with mechnical draft towers than with natural draft towers. Since the release from mechanical draft towers is made at a lower elevation, where winds are generally weaker, the saturation deficit is less, surface nocturnal inversions frequently prevail and the plumes may be trapped in building eddies due to aerodynamic downwash, the potential for including fog and icing increases. On the other hand, visible plumes are generally shorter and lower, and long plumes occur less frequently (U.S. Nuclear Regulatory Commission, 1976). A comparative analysis of cooling alternatives for Indian Point Unit 2 (U.S. Nuclear Regulatory Commission, 1976) shows that the amount of salt deposited annually from mechanical draft towers is higher, by a factor of approximately 6 in areas of maximum deposition, than is the case with natural draft towers.

6.38 Several studies have reported light, friable icing from the operation of mechanical draft towers, but there have been no reports of severe icing on roads or structures adjacent to the towers. In most cases fogging and icing would be confined to distances of 1,000 to 2,000 feet from the tower (U.S. Nuclear Regulatory Commission, 1976).

6.39 Costs. Capital costs associated with mechanical draft cooling towers are generally lower than those associated with natural draft towers. Annual operating costs, on the other hand are higher, particularly since the operation of mechanical towers involves a substantially higher consumption of power. The cost advantage of one system over the other can be established only through detailed analysis where such factors as the cost of energy can be assigned appropriate weights. In a retrofit application, as is the case at the Bowline Point station, the relative difference in total costs is expected to be minor, and, in view of the high cost of energy associated with fuel oil, it is assumed that mechanical draft towers represent a greater cost penalty than do natural draft towers.

Cooling Ponds

6.40 The minimum surface area of a cooling pond needed to reject the waste heat from the Bowline Point station is estimated to be 750 acres. This estimate is based on a thermal loading of 6.9 million BTU per hour per acre (roughly equivalent to 0.6 acres per megawatt of installed capacity) and meteorological conditions prevailing in New York City (Patterson et al., 1971). Evaporative water losses from the pond would average 6.7 million gallons per day (4,700 gallons per minute). Drift losses from cooling ponds are caused by surface winds and are generally considered negligible. The quantity and frequency of purge needed to maintain the concentration of dissolved substances in the pond at acceptable levels are unlikely to exceed the values associated with blowdown from cooling towers (average of 3,300 gallons per minute).

6.41 A cooling pond is considered to be impractical at Bowline Point because of the unavailability of an adequate expanse of suitable land in the vicinity of the generating station. The land requirements, however, could be substantially reduced through the application of spray devices designed to produce fountain-like jets of water and increase the dissipative effectiveness of a unit of surface area of pond. With full spray assistance, the required area could be reduced by a factor of 20 (McKelvey and Brooke, 1959; U.S. Nuclear Regulatory Commission, 1976). A spray pond to serve the Bowline Point station would require a minimum of 38 acres. In principle, therefore, the 53-acre Bowline Pond could serve as a spray pond to meet the cooling needs of the station. The conversion would entail the isolation of the Bowline Pond from the Hudson River at the pond inlet, with provisions made for the intake of makeup water and the discharge of blowdown.

6.42 As a first approximation, the evaporative losses from a spray pond are of equal magnitude to those from a passive cooling pond in comparable service. Spray cooling, however, generates substantial quantities of drift, estimated to amount to 0.2 percent of the water circulated through the condenser (Roffman and Van Vleck, 1974). In the case of Bowline Point station, drift losses would amount to 750 gallons per minute. Drift, together with fogging and noise, might give rise to unacceptable problems in view of the proximity of residential sections to the west and south of the pond and the Bowline Point recreational facility to the east of the pond. A buffer zone of 1,000 to 1,500 feet is needed to confine fogging and drift effects to the site (U.S. Nuclear Regulatory Commission, 1976), implying that spray modules would have to be carefully positioned in the pond. Further detailed engineering and economic analyses are needed to determine whether the spray pond alternative warrants further consideration.

Dry Cooling and Wet-and-Dry Cooling Towers

6.43 Operating experience with both dry cooling and wet and dry cooling applied to steam electric power plants is limited. Dry cooling has a long history of application to small power plants particularly in Europe and Africa. The dry cooling technique in common use, known as the direct technique, is generally not considered practical for applications to power plants with capacities larger than 350 to 500 megawatts. In the United States, a 330-megawatt coal-fired power plant in Wyodak, Wyoming will be equipped with a direct cooling system and is scheduled for completion in the near future. The cooling facility will be used in a 5-year test program, funded in part by the U.S. Department of Energy and is aimed at improving dry cooling design and operation (U.S. Department of the Interior, 1974). A second method of dry cooling known as the indirect technique is considered to be conceptually suitable for application to large power plants. There are currently no firm plans to use a system of this type in a large central station.

6.44 Both natural draft and mechanical draft towers can be used in dry cooling systems. Since the flow of air required to dissipate a given heat load is higher with dry cooling than with evaporative cooling, dry cooling towers are necessarily more massive than their evaporative counterparts. Further, the minimum temperature (of the cooling water) attainable with dry cooling is higher than or equal to the minimum temperature attainable with evaporative cooling systems (Appendix D). The penalties, in terms of loss of generating capacity and reduced operating efficiency, are correspondingly higher. Under conditions prevailing at Indian Point Unit 2, the cost of energy generated with dry cooling is estimated to be 20 percent higher than the cost of energy generated with once through cooling and 15 percent higher than the cost of energy generated with evaporative closed cycle cooling.

6.45 Several schemes have been proposed to combine dry and evaporative cooling systems and derive the benefits of dry cooling while reducing the associated penalties. A typical design objective would be to have dry cooling in operation during 95 percent of the year and resort to evaporative assistance (or, possibly, other means such as mechanical refrigeration) when ambient temperatures are highest. The idea is particularly attractive where the peak demand for power occurs during the hottest part of the year and coincides with the greatest loss of generating capacity attributable to dry cooling.

6.46 The greatest potential advantage of dry or wet and dry cooling at the Bowline Point station is associated with the reduced need for makeup water to offset the losses due to evaporation, drift and blowdown. As presently contemplated, however, an evaporative cooling system at the station could be supplied with water withdrawn to meet the power plant's service requirements. Without reducing the service requirements, this advantage would be virtually negated.

Other Cooling Alternatives

6.47 A number of other cooling alternatives might prove to be technically feasible at the Bowline Point station. The first of these is to meet the cooling needs of both units with a single evaporative cooling tower to accomodate the heat rejection load, the base area of a single tower would need to be roughly twice that of a tower designed to reject the waste heat from one of the units. In the case of a natural draft tower a commiserate increase in height would be needed to generate a flow of air adequate to effect the desired degree of cooling. Thus, a single tower would necessarily be more massive than a tower used in a dual system. In the case of a mechanical draft tower, the total number of "cells" or modules would be the same, whether these make up a single or a dual cooling system. A single tower, therefore represents a reconfiguration of the cells into a single array. From a visibility standpoint the tradeoffs involved in changing from a dual to a single system are evident. Whether this change would reduce this visual impact of the cooling system and the station as a whole remains uncertain in the absence of further study.

6.48 A second possibility is to site a single or dual tower at a location remote from the generating station. Distances of 5 miles or more between the generating station and cooling tower may be technically feasible, taking into consideration a rate of flow of approximately 375,000 gallons per minute through each of the units, a total rate of makeup of 16,000 gallons per minute and an estimated rate of blowdown of approximately 7,000 gallons per minute from the system. Conducts linking the station to the cooling system would be needed to carry the circulating water and makeup water, if the service water system is retained as the source of makeup. A conduit for the discharge of blowdown would be needed to link the cooling system to the Hudson River, the most likely waterbody to receive the discharge.

6.49 Although it is impossible to estimate the penalty in capital costs associated with a remotely sited cooling system until a precise location is selected, it may be anticipated that this penalty would be substantial. An economic penalty as well as a penalty in terms of energy would be incurred in operating the systems, that is in pumping water between the station and the cooling towers. Again, this penalty would be dependent on the separation between the facilities and, in view of the large flow rate involved is expected to be substantial.

6.50 The primary incentive in considering a remote site for the cooling system lies in reducing the visibility of the generating station with cooling towers from the Hudson River. It appears unlikely, however, that cooling towers with their plumes could be entirely concealed from the view, particularly in the case of natural draft towers. Clearly, a remotely sited cooling system would constitute a visual impact in its vicinity. In essence, therefore, a remotely sited cooling system represents a tradeoff between reducing the combined visual impact of the generating station with a closed cycle cooling system at the expense of creating two visual intrusions at separate locations. Over and above this, there remain the questions of costs, securing a suitable site, installing the necessary conduits over appropriate right-of-ways and public acceptability of the overall scheme.

6.51 Salt drift from the cooling towers has been identified and analyzed as a potential source of damage to vegetation in the vicinity of the Bowline Point station (Chapter 4). An alternative considered here to reduce the deposition of salt involves reducing the concentration of dissolved matter in the cooling water inventory. This could be accomplished by treating the makeup water, which may consist of river water and recirculated blowdown, or by obtaining and, if necessary, treating water from groundwater, municipal or other sources. As mentioned previously, a total of 16,000 gallons per minute is presently drawn as service water from the Hudson River to meet the needs of the station and the major portion of the flow could be made available as makeup for a closed-cycle cooling system. This withdrawal is equivalent to approximately 23 million gallons per day, or, on the basis of a planning factor of 100 gallons for person per day, enough water to supply a residential community of 230,000 persons. In terms of a ground water supply, yields from individual wells vary greatly with the properties of the aquifers supplying the water. To put matters in perspective, it may be noted that a well yielding 0.5 to 1 million gallons per day is generally considered to be a high capacity well. Precise estimates of the costs of desalinating river water to reduce its salinity are not available. Major desalination and treatment projects based on the reverse osmosis process are presently under construction in various parts of the world. As a general rule, the costs associated with desalination fall in the range of $0.80 to $1.30 per 1,000 gallons treated. To meet the needs of a closed-cycle cooling system at the Bowline Point station, therefore, would entail an expenditure of the order of $20,000 per day.

6.52 Another possibility which could be considered as an alternative to a closed cycle system, consists of modification to the intake structures, including barriers at the entrance to Bowline Point to reduce entrainment and impingement. These are considered in detail elsewhere in Chapter 6.

6.53 Finally, waste heat from the Bowline Point station could in principle be rejected to the Hudson River through an underwater heat exchanger. The cooling system would be entirely closed and once filled, would require only minimal makeup. While heat exchangers of appropriate design are readily available, an application of the type and scale envisaged here cannot be considered as demonstrated technology. Accordingly, the costs and reliability of such a system cannot be predicted with any degree of confidence.

Modification of the Present Permit

6.54 The specific conditions, considered as possible stipulations that might be added to the permit issued by the District in connection with the Bowline Point Generating station, all relate to the station's interactions with the aquatic ecosystem of the Hudson River estuary. These conditions are intended to mitigate damage to populations to striped bass and other fishes. Several approaches could be followed, in principle, to attain this goal. Restrictions could be imposed on the operation of the power plant so as to reduce the throughput of cooling water, thereby reducing entrainment and impingement of aquatic organisms. An alternative approach would be to reduce the impingement of fish by installing fish diversion devices and/or by modifying the intake structure, screening mechanisms and fish return facilities. Entrainment could not be reduced significantly through these latter means. Elements of both approaches might be combined into a number of more comprehensive strategies. From an operational standpoint, such strategies might involve the integration of the generation and maintenance schedules of the power plants on the Hudson River estuary and other power plants within the New York Power Pool supply system, on the basis of ecological as well as technical and economic factors.

Restricting Operation of the Plant

6.55 Measures aimed at reducing the amount of cooling water that is withdrawn from the Bowline Pond and circulated through the power plant might include restrictions to the operating schedule of the plant, reduced flow through the condenser, and operation of the plant at partial generating capacity. However, technical considerations relating to a large base-load plant like the Bowline Point Generating Station tend to limit the extent to which the plant can be operated intermittently or at reduced output. Also limited is the extent to which operating procedures can deviate from standard practices without unduly jeopardizing the plant and the reliability of the supply system.

6.56 Shutdown and startup of large steam electric units involve procedures formulated to avoid excessive thermal stresses, overheating and other conditions likely to damage the equipment. Following a shutdown, time is needed to bring the boiler and turbine generator up to operating conditions in steps that are generally more sequential than concurrent. Progressively longer procedures are followed as generating units are started up from hot, intermediate or cold conditions and these, as a general rule, prevail after shutdowns of 1 day or less, 2 to 3 days, or 3 days or more, respectively. The startup periods may range between less than 1 hour for a start from hot conditions and 6 to 12 hours or more for a cold start. Recent development work and evaluations of operating experience have underscored the importance of controlling downward temperature ramps and prewarming during cold starts, in terms of preventing damage to steam turbines and extending their operational lives (Spencer and Timo, 1974). These findings have prompted the manufacturers of turbines to recommend that warmup periods generally be extended rather than shortened.

6.57 Startup of the condenser cooling or circulating water system is also a lengthy procedure. A rapid initiation of the massive circulation subjects the equipment to a risk of damage as a result of water hammer, and steps must be taken to ensure that the system is free of air pockets before full flow is established. Procedures normally followed at the Bowline Point station require 8 to 12 hours to bring the circulating water systems up to operating conditions.* As a consequence, water is circulated in the systems at all times except during maintenance outages or other prolonged periods when the generating units are taken out of service. The flow may be reduced (1 pump per unit) when a unit is not producing power

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*Established in discussion with Orange and Rockland operating performed during site visit on 3 and 4 November, 1976.

but is generally kept at operational levels (2 pumps per unit). Flow is maintained with 2 pumps per unit operating whenever power is being generated to avoid the risk of losing a unit as a result of one pump failing.

6.58 Large generating units can operate at capacities greater than 1/4 to 1/3 of full-rated capacity (150 to 200 megawatts for each of the Bowline Point units). The quantity of waste heat rejected to the condenser cooling water varies proportionally with the power and, accordingly, the temperature rise across the condenser decreases as power is reduced, providing the circulation rate remains constant.

6.59 Each of the Bowline Point units has the capacity of operating with reduced flow in the condenser cooling system. Under throttled conditions, the flow is reduced from 316,000 to 257,000 gallons per minute through each condenser with 2 pumps per unit in operation. The temperature rise across the condenser at full load increases from 13.5 F to 16.6 F as the flow is reduced. Alternatively, a temperature rise of 13.5 F would prevail with reduced flow at 80 percent of full load, decreasing to a rise of approximately 4 F at 25 percent of full load.

6.60 Both units of Bowline Point station have been operated extensively with cooling water circulating at the reduced rate. In 1975 a circulation rate of 257,000 gallons per minute was maintained in both units practically continuously from the first days in January through the latter part of July (except during the maintenance outage of unit 1 from 8 May to 31 May, 1975).* Operating experience showed that the reduced velocity of water through the condenser tubes (from a design value of 7 feet per second to an estimated 5.5 feet per second) allowed slime to build up at higher than normal rates. Orange and Rockland has modified its procedures and now operates the units at reduced flow only when necessary to reduce impingement of fish or for other reasons related to the aquatic ecosystem.**

6.61 The characteristics of the Orange and Rockland system load (Appendix C) are pertinent factors in considering restrictions that might be imposed on the operation of the plant. Electrical load in southeastern New York, as in most areas of the country, generally increases during daylight hours, reaching pronounced peaks on weekday afternoons and evenings, and less pronounced peaks on weekends and holidays. The annual peak load of approximately 650 megawatts normally occurs on a weekday afternoon in July or August,

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*Established from plant operating records made available by Orange and Rockland.

**Established in discussions with Orange and Rockland personnel during site visit of 3 and 4 November 1976.

with demand remaining near peak conditions roughly between mid-June and mid-September. Load is relatively high between mid-December and mid-February and a secondary peak of the order of 500 megawatts is experienced in late fall or early winter. Monthly output of the system is lowest in April and May of each year. Further, Orange and Rockland's 1/3 share of the Bowline Point station represents a generating capability of 401 megawatts, equivalent to 44 percent of the company's base load capability and 39 percent of total generating capability (Appendix C). Con Edison's share of the plant, amounting to 803 megawatts, constitutes 10 percent of the system base load capability and 8 percent of total capability.

6.62 The least restrictive operating schedule for the Bowline Point station can be characterized as "last-on-first-off," meaning that alternative resources available to Orange and Rockland and Con Edison would be utilized before power is generated at the Bowline Point station. A schedule of this type was followed in 1974 during the last 10 days in May and the months of June and July, in accordance with the terms of the consent decree (Appendix B). Operation of both units at the Bowline Point station was restricted in that period to approximately 50 percent capacity until all available base load capability was committed to full load operation. The output of the Bowline Point station was then increased to meet any excess base load (continuous load) and cycled to follow fluctuations in demand of intermediate duration (12 or more hours on weekdays). Gas turbines were used in a normal manner to meet peak demand (less than 1 hour to about 12 hours). Operational data for the period show that both units were operated below full capacity during June and July. However, the amount of water circulated through the condensers was not substantially reduced, except during the last 10 days in May. Both units were off line at the time, on scheduled outage or for repairs, and no water was circulated through the plant condensers.

6.63 More restrictive conditions on the operation of the plant can be envisaged. As constraints are added, however, an increasingly larger portion of the base load would be shifted from the Bowline Point station to plants that would otherwise be retained for cycling duty. There would be an attendant penalty in fuel use and economy of generation, since such plants are generally the older, less efficient units within the system--the Lovett station in the case of the Orange and Rockland system. A further tradeoff might be involved, inasmuch as the substitute plants exert particular impacts on the environment and these might be intensified as a result of increased utilization. While current procedures and practices are followed, water would continue to be circulated through the Bowline Point station at times when its operation is restricted unless protracted shutdowns become part of the restrictions. The present overcapacity in the Orange and

Rockland, Con Edison and New York Power Pool Systems would make it possible to meet demand during most of the year for the next several years without the contribution of the Bowline Point station except when demand is at or near peak levels. Orange and Rockland would then be unable to meet its commitments from resources presently available to the system (Appendix C).

6.64 It is impossible to estimate with any degree of certainty the net advantages that the aquatic ecosystem of the Hudson River Estuary would derive from restrictions on the operation of the Bowline Point station. If circulation is maintained through the condenser cooling system while the plant is restricted to low power on zero power operations, there would be no net gain with respect to impingement. As regards entrainment, a reduction or elimination of the thermal shock undergone by aquatic organisms that pass through the condensers is advantageous. Thermal shock, however, is not the sole mechanism through which biota are injured or destroyed. Other potential causes of damage have been identified (see papers by J. R. Schubel, R. E. Manowicz and B. C. March, Jr., in Saila, 1975). These include pressure changes, acceleration, shear, abrasion, biocides when used, and possible synergisms among them. Field data collected at Bowline Point station indicate that mortality of fish larvae entrained through the plant tends to increase as the temperature rise across the condenser increases and that temperature is the main determinant of mortality among entrained organisms (Orange and Rockland, 1977a).

Improvements to Plant Intake

6.65 Ongoing research related to the protection of aquatic organisms at power plants (reviewed in, for example, Pagano and Smith, 1977; Cannon et al., 1979) suggests that several alternatives to the conventional vertical screen intake of the type installed at the Bowline Point station might be effective in reducing impingement. For convenience, these alternatives may be considered under the categories of diversion, recovery and exclusion systems, although a classification according to this scheme would not be rigorous and certain unconventional intakes may combine the features of systems classified in more than one category. Diversion systems include those based on behavioral barriers such as electric fields, air bubble curtains, sound, light, water jets and hanging chains (U.S. Environmental Protection Agency, 1976) as well as louvers and angled screens (U.S. Environmental Protection Agency, 1976 and, for example, Schuler and Larson, 1975; Taft et al., 1976; Taft and Mussalli, 1977; Mussalli et al., 1977). Recovery systems provide means of collecting impinged organisms and returning them to water. Several fish handling transport systems have been developed and tested (for example, Mussalli and Taft, 1977) and these may be used to recover organisms impinged on conventional traveling screens (for example, Eisele and Malanic, 1977) or screens of alternative designs, such as the fish bucket screen (for example, White and Brehmer, 1976) or the center flow (single-entry, double-exit) screen (for example, Passavant Corporation, undated). Exclusion systems incorporate physical barriers to prevent organisms from entering the intake structure. Among them are the infiltration devices, such as radial wells, fixed bed filters and porous dykes (U.S. Environmental Protection Agency, 1976) and wedge wire screens (for example, Johnson Division, UOP, 1977; Hanson et al., 1977; Key and Miller, 1977). Infiltration intakes eliminate or reduce entrainment as well as impingement. Other intakes that have the potential of reducing entrainment incorporate either woven screening of fine mesh (Tomljanovich et al., 1977) or wedge wire screens with narrow slot widths (Hanson et al., 1977).

6.66 Six schemes have been identified as possible alternatives or modification to the existing intakes at the Bowline Point Generating Station (Orange and Rockland, 1976). The selection of these specific schemes is based on considerations of engineering practicality and the results of flume tests with certain native fishes of the Hudson River (Consolidated Edison, 1976) as well as experience and an increasingly wide body of information reported in the literature. Four of these schemes involve traveling screens of conventional but angled or inclined to the direction of flow. In the first scheme, an approach channel would be constructed to provide the necessary angle between flow and the existing intake structure. The next two schemes involve traveling screens in a chevron configuration located respectively to the side and in front of the existing structure. The fourth scheme comprises screens located in front of the existing structure, positioned perpendicularly to the direction of flow but rotating about a plane inclined from the vertical. As part of the fifth scheme, the existing traveling screens would be replaced by fish bucket screens. A fish bypass or collection and return device would be provided in each of these five schemes. In the sixth and final scheme, a behavioral barrier would be placed at the inlet of Bowline Pond. Three possible mechanisms have been identified as possible means of diverting aquatic organisms away from the pond--an air bubble curtain, hanging chains or a water jet curtain. Any one of the suggested schemes could be implemented without disrupting the normal operation of the plant. Detailed estimates of the costs associated with these schemes are not available. Orange and Rockland considers to be in the range of $5 to $10 million.

6.67 In addition to evaluating the alternative intakes discussed above, Orange and Rockland has been testing a barrier net positioned in a V upstream of the existing intake structure (Edwards and Hutchison, 1979). The results of tests conducted at various times between November 1976 and May 1978 suggest to the investigators that impingement may be reduced by as much as 90 percent (see Chapter 4). Clogging of the screens and the gilling of fish on the nets are reported not to be significant problems. Further evaluation is needed to determine whether a barrier net could be considered as a permanent alternative to the modified intakes and whether reductions in impingement comparable or exceeding those reported for the barrier net could be achieved with the alternative intakes identified by Orange and Rockland. In addition, the selection and implementation of one particular scheme as the most suited to the situation at Bowline Point would be contingent on more extensive and detailed evaluations. It may be well to note that entrainment would not be significantly reduced through the application of any one of these techniques. Tests of a continuously traveling screen with fine mesh (2.5 millimeters) woven netting conducted at the Indian Point station suggest to the investigators that such a system would not be effective in reducing losses of striped bass in the early stages of life (Central Hudson et al., 1979). This conclusion is based on the low retention rate of eggs and larvae up to the early post yolk-sac stage and the low rate of survival among the organisms retained on the screen. Among the organisms large enough to be retained in substantial proportions, the rate of survival is reported to be comparable or less than the rate expected to prevail if the organisms were entrained through the condenser.

6.68 In view of the need for further evaluation of possible modifications to the intake existing at the Bowline Point station as well as the cost and extent of work associated with the modifications identified by Orange and Rockland, operational restrictions based on improvements of the intake are considered by the District to be more appropriately regarded as alternatives to closed-cycle cooling than as conditions that could be imposed during an interim period of operation with one-through cooling. With respect to the aquatic ecosystem of the Hudson River estuary, any reduction in the rate of impingement of aquatic organisms clearly would tend to mitigate the impacts attributed to the operation of the power plants on the river. How effective such mitigation would be in terms of populations of fish is presently unknown because of the several uncertainties discussed above and the absence of plans to take specific measures at specific power plants.

Comprehensive Management Program Within the New York Power Pool

6.69 A broad view of the ecosystem of the Hudson River estuary suggests that a comprehensive approach at managing the operation of all the power plants on the river could prove more beneficial than restricting the operation of individual plants in isolation of each other. Such an approach might incorporate considerations of the numerous species of fish that inhabit the river, their spawning and migrating habits, nursery areas, and other temporal and spatial characteristics of their life cycles.

6.70 It is conceivable that the integrated supply system of the New York Power Pool could afford the flexibility needed to develop a management strategy of power plant operation based on ecological as well as technical and economic factors. Scheduled maintenance and generation plans of the stations throughout the power pool area could possibly be coordinated to avoid affecting critical areas during critical periods or, at least, mitigating ecological damage to the extent possible with present constraints. For example, the strategy could take advantage of the temporal and spatial differences in entrainment and impingement among the power plants on the Hudson River (see discussions of entrainment and impingement in Section 4). The Bowline Point station might be operated during the primary spawning season (May and June) because of its smaller entrainment rate relative to other power plants. Other stations could be shut down for maintenance or restricted in their operation during this time, which also corresponds roughly to the spring period of low demand for electricity. In winter months when impingement is greatest at downriver plants, their operation might be restricted. Upriver plants, which cause less damage by impingement during the colder months, or plants located elsewhere in the power pool area could then be utilized more extensively to supply the needed energy. Clearly, these are suggestions derived from limited ecological information. Further analysis of available observations and acquisition of additional data would be needed to determine whether a management program of the type envisaged here would be beneficial from an ecological standpoint and, if so, to devise a comprehensive and balanced strategy. It may be well to note that the addition of ecological constraints to the technical and economic constraints presently acting on the supply system is likely to involve tradeoffs and entail costs in terms of economy and reliability of supply.

Suspension of the Permit

6.71 The District has considered a suspension of the subject permit, causing the Bowline Point Generating Station to shut down and not resume operation until a closed-cycle system is installed.

6.72 With an accelerated program of construction and commissioning, closed-cycle cooling systems at the Bowline Point station could be brought into operation within an estimated minimum period of 2 to 3 years. During this period, the generating capacity of the Bowline Point station would be unavailable to Orange and Rockland, Con Edison and the New York Power Pool. Orange and Rockland would be unable to meet its projected peak load from alternative new resources available to the company (Appendix C). On the other hand, overcapacity in both the Con Edison and New York Power Pool systems is currently such that available capability in both systems, even without the contribution of the Bowline Point station, exceeds peak demands anticipated over the next several years with acceptable margins of reserve (Appendix C).

6.73 Suspending the operation of the Bowline Point station represents a loss of operating revenues to the plant owners estimated to be in excess of $300 million per year.* Assuming the alternative generating and transmission capabilities are such that the loss of energy could be sustained without interruption of customer service, increases in fuel use and the cost of generating electrical energy are likely to result from a shutdown of the Bowline Point station. The precise magnitude of these penalties would depend principally on the thermal efficiency of the plants that generate the replacement power and, to a lesser extent, on likely additional losses in transmission. Increased fuel consumption would amount to an estimated 1.75 million barrels of fuel oil per year, with a corresponding value of $26 to $28 million.*

Revocation of the Permit

6.74 The District has considered revoking the subject permit, forcing the abandonment of the Bowline Point Generating Station.

6.75 The implication of this action would be far-reaching. As indicated previously, Orange and Rockland would be unable to meet peak loads from resources presently available to the company over the next several years without the contribution of the Bowline Point station (see Appendix C). Decommissioning the power plant would

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*Estimate based on net plant rate of 8,135 BTU per kilowatt-hour at the Bowline Point station and a heat rate of 11,000 BTU per kilowatt-hour, typical of electrical energy generation from fuel oil in the Middle Atlantic States (National Coal Association, 1975). Each kilowatt-hour generated at the Bowline Point station then represents a saving of 1,865 BTU. The 5,600 gigawatt-hours that would have to be generated by other stations represent an additional consumption of 10,500 BTU. At $15 to $16 per barrel of No. 6 fuel oil with a maximum sulfur content of 0.3 percent, the corresponding added consumption and costs are 1.75 million barrels and $26 to $28 million, respectively.

involve a substantial loss in tax revenue to the Town of Haverstraw until the Bowline Point site is redeveloped for industrial or other use. The Bowline Point station represents an investment (current cost of plant) of $250 million, exclusive of land and land rights, with a replacement value of approximately $1 billion in 1985 dollars.*

6.76 A relatively minor portion of the investment could be recovered as salvage if the plant were to be abandoned. Further benefits would be derived through the addition of replacement capacity that, in all likelihood, would not be oil-fired, and if coal-fired, might be slightly more efficient than the present equipment. The ultimate decommissioning of the plant would also remove a dominant visual feature from the vicinity of Bowline Point. As regards the population of striped bass in the Hudson River, very little would be gained by abandoning the Bowline Point station as opposed to installing closed-cycle cooling at the plant.

ALTERNATIVES RELATED TO THE ROSETON GENERATING STATION

6.77 The options available to the District in the case of the Roseton Generating Station are essentially the same as those discussed previously in connection with the Bowline Point Generating Station, namely, to retain, modify, suspend or revoke the District's permit issued to Central Hudson. The Bowline Point and Roseton Generating Stations are technically similar and their interactions with the environment are comparable in nature, if not precisely in degree. Accordingly, the implications associated with each of the alternative actions follow close parallels in both instances.

Retention of the Present Permit

6.78 The terms of the National Pollutant Discharge Elimination System permit authorizing the discharge of waterborne contaminants from the Roseton Generating Station require that operational levels of closed-cycle cooling be attained by 1 July 1981. Retention of the District's permit to Central Hudson, therefore, would allow a period of unrestricted operation of the plant with open-cycle cooling until 1 July 1981 or throughout the operational life of the plant, if the

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*A breakdown of the current cost of plant is: land and land rights $1,100,760, structures and improvements $42,772,050, equipment costs $207,225,810, representing a total cost of $251,098,630 or $202 per kilowatt installed (U.S. Federal Power Commission, Form 1, Annual Report of Orange and Rockland Utilities, Inc. for year ended 31 December 1976. Replacement costs are computed on the basis of $820 in 1985 dollars per kilowat of installed coal-fired capacity.

requirement for closed-cycle cooling at the Roseton station is ultimately waived by the U.S. Environmental Protection Agency.

6.79 The impacts resulting from the operation of the Roseton station with open-cycle cooling are those documented in Chapter 4 of this statement. The major advantage of installing closed-cycle cooling at the facility stems from reducing the potential of damaging the aquatic ecosystem of the Hudson River by reducing the rate at which cooling water is withdrawn and discharged. To accomplish this goal, the installation of any one type of closed-cycle cooling system found to be practical for the Bowline Point station is considered technically feasible at the Roseton station. The related monetary costs and other impacts, such as land and water use, the release of water vapor and spray to the atmosphere, noise and the visual features of the cooling system, would be similar to those associated with closed-cycle cooling at the Bowline Point station.

6.80 Without additional encumbrances imposed by the District, the Roseton station would continue to generate electrical energy as efficiently, reliably and economically as possible and to satisfy, in part, the needs of residential, industrial, commercial and public consumers served by Central Hudson, Con Edison, Niagara Mohawak and the New York Power Pool (Appendix C). The transition to closed-cycle cooling, if carried out within the time frame currently specified in the National Pollutant Discharge Elimination System permit, would be orderly.

Modification of the Present Permit

6.81 Concern over the continued operation of the Roseton facility, in common with the other power plants on the Hudson River Estuary, centers principally on the impairment of the aquatic ecosystem as a result of entrainment and impingement of organisms. Estimates based on the field data available suggest that the number of organisms entrained by the Roseton station may be substantial in comparison to other plants but mortality due to impingement is relatively minor. The analysis dealing with striped bass shows that the impact attributable to the operation of the Roseton facility with once-through cooling is small in terms of the net effect on the adult population and in comparison to the overall effect of all power plants on the Hudson River. The installation of closed-cycle cooling at the Roseton station alone, with all other stations remaining on open-cycle cooling, would reduce the riverwide losses of yearlings and the adult standing stock by only a small amount below the losses predicted for all plants with once-through cooling.

6.82 On the basis of these findings, measures to reduce the intake of cooling water by restricting the operation of the Roseton station and to reduce impingement through modification of the intake structure or behavioral screening systems would be of lesser value at the Roseton station than at the Bowline Point station. In the context of a comprehensive (including environmental considerations) program to manage the operation of power plants on the Hudson River and in the New York Power Pool, steps could be taken to utilize the Roseton facility sparingly at times when entrainment of fish eggs and larvae might present a problem, and more intensively at times when the operation of other plants within the system would be most detrimental from an ecological standpoint. It is emphasized that statements made here in connection with alternatives related to the Roseton station are based on limited field data collected in 1974, when both units were first brought into service, and early in 1975. These statements would remain valid largely if field monitoring continues to reveal a relatively low level of impact on the aquatic ecosystem resulting from the operation of the Roseton station.

Suspension of the Permit

6.83 A suspension of the District's permit related to the Roseton Generating Station would cause the station to be shutdown for an estimated 2 to 3 years while closed cycle cooling is installed. Without the contribution of the Roseton station, both Central Hudson and Niagra Mohawk would experience difficulty in maintaining an adequate margin of reserve with the remaining resources currently available to these systems (Appendix C). Reserve margins in the Con Edison and New York Power Pool would not be reduced below acceptable levels in the near-term future if the Roseton station were to be shut down temporarily (Appendix C).

6.84 Suspending the operation of the Roseton station represents a loss of operating revenues to the plant owners estimated to be of the order of $300 million per year. The generation of replacement energy by alternative power plants is likely to involve an increased usage of older, less efficient equipment with a corresponding penalty in fuel consumption. The increased fuel consumption is estimated to be of the order of 2.5 million barrels of fuel oil per year, with a 1976 spot market value in excess of $37.5 to $40 million per year.

6.85 Suspending the Roseton permit during the 2 to 3 years necessary to build cooling towers would result in only a negligible incremental benefit to the striped bass population.

Revocation of the Permit

6.86 Revocation of the Roseton permit would lead to the abandonment of the station currently valued at $250 million, exclusive of land and land rights (U.S. Federal Power Commission, Form 1, Annual Report of Central Hudson Gas and Electric Corporation for year ended 31 December 1976). The replacement value of the generating capacity is estimated to be in excess of $1 billion in 1985 dollars. In terms of the population of striped bass in the Hudson River, the analysis discussed previously shows that relatively little would be gained by abandoning the station as opposed to installing closed-cycle cooling at the station.

CHAPTER 7

THE RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

7.01 The relationship between the short-term use of the Hudson River for power generation and the long-term productivity of the estuary may be considered in terms of spreading urbanization on the one hand and the inherent value of the natural resource on the other. Both the Bowline Point and Roseton generating stations form part of a broad pattern of urbanization in the lower Hudson River Valley. Together with other existing power plants on the river, they represent examples of the traditional practice of locating generating facilities in relative proximity to the load centers they serve, on sites with adequate supplies of water to satisfy the operational needs of the power plants and capable of accommodating modest expansions of the facilities.

7.02 As such, the stations introduce no new trends in siting and neither strongly promote nor inhibit human development of the area. The visual prominence of the stations contributes heavily to the industrial character of the riverfront in their vicinities, but, by virtue of their locations and the long-established tradition of industry and commerce on the river, the stations are not unique features. There is no evidence that the presence of the power plants has given rise to any unusual pattern of land use in the valley nor that future land use plans might be unduly influenced by the existing facilities. Nonetheless, the stations are visually obtrusive and may be regarded as a detraction from the natural scenic beauty of the valley. In this respect, they do represent a compromise of the long-term productivity of the area.

7.03 Man's influence on the Hudson River estuary has been sufficiently extensive and prolonged to alter virtually all of the native upland ecosystems of the valley. The varied land forms, however, provide habitat for a number of plant and animal species, reflecting in their diversity and distribution the past and present uses of land on the riverbanks.

7.04 Despite development of the shoreline for industry, transportation, agriculture, residential and recreational uses, and the effects of a long history of water pollution, the wetlands remain productive. The aquatic ecosystems of the estuary, although altered somewhat by man's activities, in all likelihood remain essentially those present before intensive settlement of the area, notwithstanding the evident reduction in sturgeon, shellfish and other characteristic aquatic life. There is little doubt that the biological productivity of the area has been diminished by some of man's previous and continuing activities on the estuary. Regarding these activities as short-term uses of the environment, it is clear that long-term productivity of the estuary has been reduced. To the extent detailed in Chapter 4, the Bowline Point and Roseton Generating Stations as well as the other power plants on the Hudson River estuary give rise to impacts and, thus, can be considered in terms of short-term uses of the environment. A remote possibility exists that the continued operation of these power plants will lead to irreversible changes (Chapter 8).

CHAPTER 8

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

8.01 The Bowline Point and Roseton Generating Stations are major engineering projects that represent a substantial commitment of resources. Materials, energy and labor have been irretrievably committed in constructing the power plants. Their operation involves a continuing commitment of fuel oil and labor. Rejection of waste heat from the power plants promotes evaporation of the condenser cooling water or a loss of water to the atmosphere. With respect to the Hudson River estuary as a water resource, this loss may be regarded as irretrievable. Land dedicated to the power plants and related facilities, although not an irreversible or irretrievable commitment in the strictest sense, is likely to remain in use for power generation or other industrial purposes well beyond the operational life of the present generating units. The commitment of land to industrial purposes may be considered permanent. Biological resources have been and continue to be committed. A reduction in biological productivity results from the removal of potential habitat for fish and wildlife by the power stations and their continued interactions with the environment. Of primary concern are the impacts that the power plants exert on the aquatic ecosystem of the Hudson River. The operation of the power plants lead to the destruction of fish and other aquatic organisms. Their loss to the ecosystem is irretrievable. The question of whether this loss will lead to a significant alteration or an irreversible change of the ecosystem has not been fully resolved.

COMMITMENTS AT THE BOWLINE POINT GENERATING STATION

8.02 The Bowline Point Generating Station occupies a 245-acre tract, which includes the 53-acre Bowline Pond and 11-acre Bowline Point public recreational facility. A short corridor (3.4 miles) links the station to transmission facilities that existed prior to the construction of the power plant.

8.03 Areas were drained and filled in preparing the site for the project. More extensive portions of the site were cleared of vegetation and refuse and graded. Construction work on structures, roads, access facilities, parking lots and other paved surfaces and landscaping has been completed. Development of the site entailed the loss of an estimated 60 acres of wetlands and a loss of habitat for upland species not adapted to a mix of urban, surburban and industrial conditions.

8.04 The station structures and equipment represent a permanent commitment of construction materials, such as cement, sand, gravel, lumber, masonry, structural steel and steel siding, and a wide variety of manufactured items ranging from boilers, turbine generators, pumps and other large components to valves and plumbing supplies. Although a portion of the commitment may be salvageable and reusable on decommissioning the station, the major part is irretrievably committed.

8.05 Operation of the Bowline Point station at full power entails the consumption of fuel oil at the rate of 1,897 barrels per hour. The corresponding annual consumption is approximately 10 million barrels at a load factor of 0.66. Water losses due to the rejection of waste heat are about 30 cubic feet per second. The installation of closed cycle cooling would increase the evaporative loss of water by 10 cubic feet per second. Minor quantities of expendable material supplies, such as chemical compounds used in water treatment and equipment cleaning, maintenance supplies, detergents and sanitary products are consumed each year.

8.06 The withdrawal of water from the Hudson River for condenser cooling and other purposes gives rise to the destruction of fish and other aquatic organisms through entrainment and impingement. The continued destruction of striped bass and other species by the Bowline Point and other existing stations would lead to a reduction in the adult standing stock in the Hudson River.

8.07 The term irreversible (or permanent) as applied to the effect of entrainment or impingement on a population of striped bass has the ecological connotations of: (1) bioligical extinction (no striped bass of any age class in the Hudson River for all time), (2) fishery extinction (such small striped bass population spawning in the Hudson River as to be insignificant in its contribution to the sport and commercial striped bass fishery for all time), or (3) permanent reduction (but above the fishery-extinction level) in population size which continued after the stress is removed.

8.08 Biological or fishery extinction due to entrainment and impingement of striped bass eggs, larvae, and juveniles is only a remote possibility, even with once-through cooling at all power plants on the Hudson River. Factors preventing extinction may include the occurrence of occasional strong year classes that could possibly offset several years of power plant impact. Recruitment of spawning fish from other Atlantic coastal stocks is also possible, although the extent of its potential occurrence is presently unknown.

8.09 A permanent reduction in the striped bass population size is ecologically possible. If one component of a biological community is selectively stressed so that the population is reduced to low levels for many years, a permanent change may occur in the structure of the system of which the species is a part and the population may be unable to return to the original size after the stress is removed. However, the possibility of causing an irreversible change in the population of striped bass is not presently considered as a matter of primary concern.

8.10 Any reduction in the stock size of striped bass or other species resulting from the power generation activities on the Hudson River must be considered an irretrievable commitment of that biological resource for the period over which the reduction remains in effect. The fishery yield lost during the period of reduced stock level would also be irretrievable.

COMMITMENTS AT THE ROSETON GENERATING STATION

8.11 The Roseton Generating Station occupies a 133-acre tract of land. A small pond on the site, previously used for fly ash disposal, has been filled in developing the site. No wetlands have been affected by the construction of the station.

8.12 The commitment of materials, energy and labor in constructing the Roseton station is similar to that described previously in connection with the Bowline Point station. Operation of the Roseton station involves the consumption of approximately 12 million barrels of fuel oil per year. Evaporative losses of cooling water presently amount to an estimated 35 cubic feet per second and would increase to 42 cubic feet per second if an evaporative closed cycle cooling system is installed.

8.13 Impacts on the aquatic ecosystem of the Hudson River estuary resulting from the operation of Roseton station are similar in nature, if not in degree, to those associated with the Bowline Point station. As mentioned previously, the continued operation of these two stations in combination with other existing facilities on the river might lead to irreversible changes in the ecosystem. There is substantial doubt, however, that this event is likely to cocur.

CHAPTER 9

COORDINATION WITH OTHERS AND COMMENTS AND RESPONSES

PUBLIC PREPARATION

9.01 In preparing the Draft Environmental Impact Statement, the District contacted a large number of Federal, state and local governmental agencies, institutions, commissions, societies and corporations, with the primary objective of including all important studies and elements of information in the development of the statement. Additionally, the District obtained literature searches on topics pertinent to the generation of electrical energy on the Hudson River from the National Technical Information Service (U.S. Department of Commerce, 1976c) and the Atomic Industrial Form (Atomic Industrial Forum, 1976), and the Smithsonian Science Information Exchange, Inc. (Smithsonian, 1976).

9.02 The District informed the U.S. Environmental Protection Agency, Region II and the U.S. Department of the Interior, Northeast Region of its obligation relating to the Bowline Point Generating Station and the Roseton Generating Station by letters dated, respectively, 15 and 16 November, 1976 (Appendix B). Contact was made with the U.S. Federal Power Commission, Bureau of Power and the Acting Regional Engineer, New York Regional Office to identify sources of information pertaining to the need for electrical power in the State of New York and other matters that might involve the Hudson River. Information on wildlife, fish and fisheries was requested from the U.S. Department of the Interior, Fish and Wildlife Service and the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

9.03 Several officials were contacted in the New York State Executive Department, Office of Parks and Recreation; the Department of State, Division of State Planning; the Department of Public Service, Public Service Commission; and the Department of Environmental Conservation, Division of Air Resources, Division of Fish and Wildlife and Division of Pure Waters. Information on land use was obtained from the appropriate New York State offices, the planning departments of most of the counties within the study area and the Tri-State Regional Planning Commission. Socioeconomic data pertaining to localities of interest were obtained from officials in county and township governments.

9.04 Informed individuals at a number of universities, institutes and public associations, including New York University, Cornell University, Dutchess County College, Boyce Thompson Institute, Natural Resources Defense Council, Regional Plan Association and Mid-Hudson Pattern for Progress, Inc. were contacted. Field data and other pertinent information were requested and obtained from Utility companies that operate power plants on the Hudson River, namely, Orange and Rockland, Consolidated Edison, Central Hudson and Niagara Mohawk and from the New York Power Pool.

GOVERNMENTAL AGENCIES

9.05 Comments on the Draft Environmental Statement were received from the following governmental agencies:

Federal Agencies

Department of Agriculture, Forest Service
Department of Agriculture, Soil Conservation Service
Department of Commerce, Assistant Secretary for Science and Technology
Environmental Protection Agency, Region II
Department of Health, Education and Welfare, Office of the Secretary
Department of Health, Education and Welfare, Region II
Department of Housing and Urban Development, Area Office
Department of the Interior, Office of the Secretary
Department of Transportation, Federal Highway Administration
Department of Transportation, Regional Representative of the Secretary

State of New York

Department of Environmental Conservation
Department of Law
Metropolitan Transportation Authority

CITIZEN AND OTHER GROUPS

Comments were received from the following groups:

Utilities

Central Hudson Gas and Electric Corporation
Consolidated Edison Company of New York, Inc.
Orange and Rockland Utilities, Inc.

Other Parties

National Audubon Society
Natural Resources Defense Council, Inc. on behalf of the Hudson River Fisherman's Association
Save Our Stripers, Inc.

LETTERS OF COMMENT

9.06 All letters of comment received on the Draft Environmental Impact Statement are reproduced in Appendix A. Comments to which responses have been prepared in the Final Environmental Impact Statement are indicated in the margin of each letter. Each letter is numbered and comments are numbered consecutively within each letter. Responses to these comments are given in Chapter 10.

CHANGES TO THE DRAFT ENVIRONMENTAL IMPACT STATEMENT

9.07 Comments received on the Draft Environmental Impact Statement and new data that have become available since the Statement was issued, have resulted in revisions to several sections of the Statement. The availability of new data and technical testimony submitted as part of the on-going adjudicatory hearings among the Utilities and the U.S. Environmental Protection Agency have resulted in extensive revisions to the impact analyses of entrainment, impingement, and long-term reduction in adult fish populations in Chapter 4. Additionally, the computer analysis of the thermal impact of cooling water discharges was expanded to include a simulation of conditions that could result during a drought year. Corrections were also made to the input conditions of the computer analysis of salt drift from cooling towers and the results computed on a monthly rather than a yearly basis. A drought year was also included in the analysis of salt drift. In Chapter 6 (Alternative Actions), more cooling alternatives have been discussed and a section on potential improvements to intake structures has been added. Other changes to the text resulting from responses to comments did not materially change the findings as originally presented. These text changes are noted in response to comments given below.

RESPONSE TO COMMENTS RECEIVED ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT

9.08 Responses to the letters of comment on the Draft Environmental Impact Statement reproduced in Appendix A are given below. Each comment to which a response has been prepared is indicated by a vertical line in the margin of the letter in Appendix A. Each letter has been given a number and comments within each letter have been numbered consecutively so that every comment has a unique hyphenated number that identifies it as to the letter it is from and which comment it is within the letter. For example, Comment 14-23 would be comment 23 from letter 14.

9.09 The response is given immediately below the comment. In some cases, the original comment has been summarized, paraphrased or shortened for inclusion here. In such cases, the reader may check the original letter in Appendix A for the full text of the comment.

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE

Comment 1-1

Continued operaiton of Bowline Point Station would have no significant effect on forested land, beyond that referred to in our comments of 1973.

Response

Since the chronic effects of salt drift to vegetation are unknown, and the potential acute, visible impacts can be assessed only for less than 5 percent of the species occurring in the South Mountain-High Tor State Park Forest, a determination of "significant effect on forest land" would be prelimiary at best (see paragraph 4).

Comment 1-2

Direct damage to plants from salt would be temporary as stated in paragraph 4.82, pp. 4-47 and 4-48 of the DES. If soil salt content should approach the threshold of damage for dogwood and other sensitive tree species, more resistent species could be substituted.

Response

A generalization that salt drift damage would be temporary is not justified due to the paucity of drift experiments (see paragraph 4). Replacing damaged residential and urban ornamentals with resistant forms would be feasible. An attempt to substitute salt-drift resistant species in natural ecosystems would probably result in greater environmental impacts from physical disturbances, such as trampling and rooting, than if natural recolonization of affected sites were allowed.

U.S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, NATIONAL MARINE FISHERIES SERVICE

Comment 4-1

We recommend that the Corps of Engineers consider the alternative in which the present permit be modified to follow the major stipulation found in the National Pollution Discharge Elimination System permit issued by the U.S. Enviornmental Protection Agency.

Response

The alternative of closed cycle cooling is one of the alternatives included in the EIS, and will be considered by the Corps in any subsequent actions which may be taken with respect to modification, suspension or revocation of the outstanding permits.

U.S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, ENVIRONMENTAL RESEARCH LABORATORIES.

Comment 5-1

Although the report summary concludes from monitoring data that in no instance were the air quality standards exceeded, a numerical simulation discussed in Section 4.54 showed 24-hr average SO_2 concentrations would exceed standards on the High Tor ridge line near the plant. Furthermore, attempts to monitor the ridge location produced inconclusive results because of the apparent sporadic nature of the monitoring and tracer test program. In fact, the report goes on to say in Section 4.56 that the possiblity of exceeding SO_2 standards could not be ruled out on the basis of the surveys. The implication in the summary of adverse environmental impacts (page iv) is otherwise.

Response

The conclusion reached in paragraph 4.56 of the DES is based on a partial analysis of available information. A complete analysis leads to the conclusion now set forth in the FES, namely, that, on the basis of both observations and consideration of meteorological records, the possiblity of contact between the plume and the High Tor ridge is remote.

U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION II

Comment 6-1

The EPA recommends that a final EIS not be issued until EPA's adjudicatory hearings are ended and a decision on the closed-cycle requirement is rendered.

Response

The Corps is preparing the EIS pursuant to the time requirements of a court approved schedule which is embodied in the Final Order. The court, in establishing its deadline, was aware of the ongoing EPA hearings dealing with closed cycle cooling, then in progress but did not link the Corps' obligation to file its final EIS on the progress or completion of those hearings. The recommendation contained in these comments is therefore in conflict with the Final Court Order, which imposes on the Corps a time limit with respect to filing the Final EIS. It should be noted, however, that the EIS has included in its discussion of the alternative of closed cycle cooling all information and data developed to data in the on-going EPA adjudicatory hearings dealing with this subject.

Comment 6-2

Air quality data and modeling results indicate that the source does not violate the National Ambient Air Quality Standards.

Response

Comment noted.

Comment 6-3

In light of these comments and in accordance with EPA Procedure, we have classified this draft EIS as ER-1, indicating environmental reservations on the undisclosed Corps proposal (ER) and information sufficient for each a determination (1).

Response

Comment noted.

U.S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE, OFFICE OF THE SECRETARY

Comment 7-1

We noted that the impact on the quality of river water as related to the marine life is addressed, including maintenance of water quality (SB) level necessary to permit swimming. However, it is also noted that there is a need for upgrading the existing quality level to provide a potential backup potable water source. The effect on this potential source from the discharge of boiler blowdown and other chemicals should be addressed.

Response

As indicated in paragraph 2.33 of the DES, water quality over the portion of the Hudson River estuary roughly between mile points 30 and 60 is generally good (Classes SB and B) but unsuitable for municipal water supply because of the intrusion of saline water. Both the Bowline Point and Roseton stations are on this section of the estuary. Attention to the Hudson River as a potential source of water for the regional supply system has, to date, focused on the reach of the estuary between mile points 86 and 95 (paragraph 1.103 of the DES). Beyond the consideration of the remoteness and downstream location of these power plants from the possible source of potable water, it may be well to note that the release of contaminants from the power plants in quantities meeting limitations imposed through the National Pollutant Discharge Elimination System permit is not expected to cause any appreciable degradation in the quality of the receiving waters (paragraphs 4.40, 4.44, and 4.47 of the DES).

Comment 7-2

The emissions from the power plant (or plants) are addresssed in terms of both the local effect and the additive effect on the quality of the air shed. Analysis of the impact on human health would be essential in order to complete the assessment.

Response

The impacts that the Bowline Point and other generating stations on the Hudson River exert on the quality of the air shed are analyzed in terms of compliance with or possible violations of regulatory standards. These standards, of course, are set on the basis of public safety and welfare so that further considerations of human health, particularly where all applicable standards are being met, appears to be beyond the scope of the environmental statement.

Comment 7-3

The entrance into the food chain (sport fish) of the chemicals resulting from power plant operation and their potential for biomagnification needs analyses and assessment.

Response

The chemicals that may be discharged into the aquatic environment as a result of power plant operations are described in Table 4-1 and Appendix D.3-D.5. Most of these compounds are various acids and bases used for cleaning and preventing corrosion of equipment and would not be expected to bioaccumulate in aquatic organisms. Only one heavy metal, chromium in sodium dichromate ($Na_2Cr_2O_7$), is known to be present among these chemicals. Although some aquatic organisms may bioaccumulate chromium from low concentrations in the ambient environment, chromium has not been reported to biomagnify sequentially through the food chain. For several of the chemicals used, the composition is unknown and proprietary to the developing company (e.g., Drew Gard-100, Vertan). Those proprietary chemicals containing any of 129 Federally designated "priority pollutants" are undergoing evaluation by the U.S. Environmental Protection Agency (U.S. Environmental Protection Agency, 1979).

Comment 7-4

In summary, the potential for impacting public health and safety should be addressed in order to complete the statement.

Response

Public health is the primary focus of the District's analysis of the effect of the Bowline Point and the other generating stations on air quality and water quality in the study area. Public safety is considered specifically in paragraphs 4.229 and 4.230 of the DES in terms of potential accidents at the Bowline Point stations and in the transportation of fuel to the station.

U.S. DEPARTMENT OF THE INTERIOR, OFFICE OF THE SECRETARY

Comment 10-1

Several undocumented assertions occur in the draft statement. For exmaple, on page 4-10, it is stated that "In terms of the flow regime of the lower Hudson River, the evaporative losses of water caused by the rejection of waste heat from existing power plants are considered to be negligible." Such statements should be fully referenced and supported since we question that it can be properly concluded that these effects are negligible.

Response

Consumptive use of water associated with the rejection of waste heat from all of the existing power plants on the Hudson River estuary is estimated by the District to be of the order of 70 cubic feet per second (paragraph 4.24 of the DES). This estimate is based on duly referenced information supplied by the U.S. Environmental

Protection Agency, generally applicable rules-of-thumb taken as assumptions in the DES and well established physical constants. A comparison is next made between a consumption of 70 cubic feet per second, considered by the District to be a high or upper estimate and an average annual flow of 13,000 cubic feet per second gaged at Green Island, upstream of all the power plants under consideration. Considering further that the freshwater flow is augmented by an unknown amount supplied by three major tributaries downstream of the confluence of the Hudson and Mohawk Rivers--identified by the U.S. Department of the Interior as the Wallkill River and Kinderhook and Rondout Creeks (paragraph 2.25 of the DES)--the District concludes that the evaporative losses of water are negligible in terms of the flow required of the lower Hudson River.

In terms of depleting the freshwater resource, the District notes in its analysis that the major portion of the installed capacity on the Hudson River is on a reach considered unsuitable for municipal water supply because of the intrusion of saline water.

Comment 10-2

In several places in the draft statement, for example, paragraphs 4.180 to 4.183, the staff concludes that more accurate and reliable assessments of potential impacts might be possible if additional data were collected. Any request for additional studies should be predicated on an extreme need for specific types of information and a high probability of obtaining that information.

Response

Comment noted.

Comment 10-3

The Corps' acknowledgement on page 4-63 that 1974 was characterized by "exceptionally low freshwater flow" in the Hudson River introduces considerable reason for concern. Entrainment and impingement analyses for Bowline rely heavily on field data collected in 1974. Those data serve as input for very important model runs which may serve to identify alternate decision options. Basic questions regarding the representative nature of 1974 data and its incorporation into 40-year predictive models should be addressed.

The above statement on low flow could be correlated with the statement at the top of page 4-5 indicating that 1974 is "a year considered to be typical." Similarly, the table of Hudson River flows on page 2-15 should be correlated with the statement on page 4-63 concerning low freshwater flows.

Response

Comment 10-4

The draft statement on page 4-70, concludes that yolk-sac larvae of the Atlantic tomcod are most numerous downriver of Haverstraw Bay and, therefore, that this distribution greatly reduces their entrainment at Bowline. An equally credible conclusion is that the observed distribution, with a general downriver maximum density, is a direct result of entrainment and impingement at upriver power plants. The consequences of this alternative interpretation of existing data should be explored thoroughly in the final environmental statement.

Response

This statement has been deleted from the FES.

Comment 10-5

There is no evidence that the use of a Ricker-type function is valid in estimating long-term impacts to white perch, Atlantic cod-tomcod, and American shad. This largely invalidates any conclusions obtained by use of equilibrium reduction equation, regardless of the confidence with which impingement and entrainment losses might be estimated.

Response

A discussion of the use of the Ricker formulation to describe the population dynamics of Hudson River fish populations begins at paragraph 4.229.

Comment 10-6

For purposes of estimating entrainment mortality at Bowline and other power plants along the Hudson, the Corps selected intake f-factors (f_1) of 0.5 and 1.0. The rationale for using 0.5 and 1.0 is unclear. The final statement should include analyses and discussions of model predictions (percent reductions in adult stocks) based on values of 2.0, 5.0, and 10.0.

Response

The model used in the DES by Oak Ridge National Laboratory to estimate long term reduction in the adult striped population is not used in the FES.

Comment 10-7

The implicit conclusion from the discussion on page 4-70 and 4-71 of the dES is that blueback herring and alewife will sustain only slight entrainment losses because they spawn north of the river's power plants is suspect. The conclusion is dependent on the mistaken assumption that early life stages of blueback herring and alewife are distributed very similarly to American shad. This is not true. In fact, herring and alewife are more abundant in downstream areas as opposed to shad which occur in greatest numbers farther north. See Lawler, Matusky and Shelly (1977a, 1977b). The erroneous conclusions presented in paragraphs 4.159, 4.160, and 4.175 of the DES must be considered in light of these recent references.

Response

These sections have been eliminated from the DES and replaced with more recent information in the FES.

Comment 10-8

The draft statement on page 4-88 summarizes the utility companies' position concerning density-dependent growth, namely that there exists "...a significant negative linear correlation relating young-of-the-year density and growth for striped bass in the Indian Point region." This is inaccurate. A more recent report submitted by the companies points out that data presently available do not substantiate the relationship postulated earlier.

Response

More recent analyses by the Utilities have found a significant negative correlation between striped bass young-of-the-year population size and growth rate. Review of these data by the staff of the U.S. Environmental Protection Agency and their consultants indicates that this relationship cannot be substantiated. A discussion of this issue begins at paragraph 4.212.

Comment 10-9

The draft statement uses an estimate of striped bass mortality at the proposed Cornwall plant. This estimate is in error.

Response

Because of the uncertainty of implementation of the Cornwall project, its potential impacts are not considered in the FES.

Comment 10-10

Other than general statements about the species composition, relative densities and seasonal changes in Bowline Pond, the draft statement provides little useful information to describe fish populations.

Response

All presently available data on fish eggs and larvae in Bowline Pond has been summarized in the FES (Paragraphs 2.95 and 4.124). References to pertinent site-specific studies are provided if more details are desired.

Comment 10-11

There is general agreement that some adverse impacts, particularly those to striped bass, are regional--not localized. The precise geographic and numerical bounds of those impacts remain points of controversy. Nonetheless, relative to the discussion on page 4-1, it is important that the Corps of Engineers recognize the significance of the regional impacts of the Bowline plant and not rely solely on an assessment of cumulative power plant impacts to address regional concerns.

Response

A note has been added to paragraph 4.01 of the FES to indicate that, where appropriate, the analysis encompasses potential impacts of a regional character experienced beyond the limits of the study area.

Comment 10-12

The treatment on page 4-103 in the DES of the contribution of Hudson River striped bass to the Atlantic coastal population is vague and brief. The "contribution" issue deserves more thorough treatment in the final environmental statement.

Response

The issue concerning contribution of Hudson River striped bass to the Atlantic fishery is discussed in more detail in the FES, paragraphs 2 and 4, and Appendix D.

Comment 10-13

The assertion on page 3-6 of the draft statement, that the existing Bowline facility represents a "baseline or initial condition for future planning," requires further explanation. In our view, it fails to recognize the intent of Congress when it passed Public Law 92-500. We believe that the Federal Water Pollution Control Act Amendments of 1972 do not provide for, *a priori*, facilities such as Bowline as necessary contributors to water pollution. To the contrary, several sections of that Act, most notably 316(a) and 316(b) were intended to discourage such assumptions.

Response

This statement, contained in paragraph 3.23 of the DES, does not add substantively to the understanding of the relationship between the Bowline Point generating station and land use planning on the Hudson River estuary. It has been deleted.

Comment 10-14

The conclusion that Bowline Point Generating Station is not likely "to present an unusual constraint in devising plans to guide and control further growth" requires clarification. If the facility is permitted to operate with once-through cooling, it may very well influence future development along the Hudson River. Simply on the basis of water withdrawals and accompanying aquatic impacts, operation with closed-cycle cooling is preferred to once-through cooling. Closed-cycle cooling requires only 2 to 5 percent of the water used in once-through systems. A similar reduction in aquatic impacts could very easily influence future uses of the Hudson River Estuary.

Response

This statement contained in paragraphs 3.23 of the DES does not add substantively to the understanding of the relationship between the Bowline Point station and land use planning on the Hudson River estuary. It has been deleted.

Comment 10-15

We are pleased to note that the draft environmental statement, on page 3-3, recognizes the work proceeding under the current Hudson River Basin Level B Study. Any further studies or project implementation phases should be related to the findings of the basin-wide study.

Response

Comment noted.

Comment 10-16

The discussions in paragraph 4.85, on page 4-48 of the DES has not demonstrated that plants are more likely to be adversely impacted by average annual concentrations of salt in the air and rates of deposition of salt than by concentrations and depositions of greater magnitude and shorter duration. The entire discussion and analysis of potential impacts from salt depositionis keyed to average annual predictions. The usefulness of such an approach is questionable in the absence of more specific information concerning lethal exposure thresholds, acclimation capabilities, and duration-magnitude projections. The final statement should be expanded to cover these additional considerations.

Response

The DEIS discussions in paragraph 4.85 have been revised using the only reliable information available (see paragraphs 4.84 and 4.101). Lethal exposure thresholds and acclimation capabilities are not known, and duration magnitude projections cannot be made. The limitations of the salt drift impact assessment in the FEIS are explicitly stated in paragraph 4.86.

Comment 10-17

Sections 2.123 and 2.124 on page 2-67 of the draft statement provide only scant information concerning existing recreational resources of the area under study. The basic listing of activities presented should be complemented by identifying some of the major attractions or by tabulating the total overall activities. For example, the total number of boat slips and boat ramps within view of the plant sites under study should be tabulated as should the total number of marinas and river access points near the plant sites. Major marinas or access points should be identified. The area could be overflown on randomly selected days to count the recreational vessels on the river to obtain estimates of boating use.

Response

Since the Bowline Point Generating Station is built and has been in operation for a number of years, its visibility is taken as the major source of potential impact on recreational facilities in the vicinity of the station. Considerable attention is given in the DES to the visual intrusion of the power plant (for example, paragraphs 4.220 through 4.224 and 5.02 of the DES) and the emphasis placed on its visual impact by the Hudson River Valley Commission in reviewing the Bowline Point project (paragraphs 1.57 and 3.18 of the DES).

From its analysis, the District has concluded that the visibility of the power plant and other aspects of the plant's operation relating directly to the human resources of the study area (paragraphs 4.216 through 4.236 of the DES) have not discernibly affected local land use, property values in the area of patterns of urbanization, industrialization and business activities (paragraphs 3.06 and 3.11 of the DES). Further, the public recreational facility provided in part by Orange and Rockland has proved to be a popular local attraction in spite of its close proximity to the power plant (paragraphs 1.43 and 3.07 of the DES).

For these reasons, the District does not consider the visual impact of the Bowline Point stations, in terms of its effects on local recreational amenities, to be a matter of substantive concern. Accordingly, the effort needed to cataloge the recreational facilities within the viewshed of the power plant, to estimate the usage of these facilities, and next to attempt to make comparisons between the preconstruction and operational phases of the Bowline Point project appears to be unwarranted. The District does recognize that the visibility of the station may inhibit certain types of residential, commercial or recreational developments in its vicinity (paragraph 3.11 of the DES). It may be well to note here that none of the comments on the DES point to any significant adverse impact on recreational facilities experienced since the construction of the Bowline Point station.

Comment 10-18

Swimming areas and camping areas within view of the plant sites should be identified with a measurement of acreage and river frontage. State parks in the area should be identified with data concerning acreage, annual visitation, shore frontage, distance to plant sites, vista intrusion, types of activities included. Valley resorts and clubs impacted by the visual intrusion on recreation sites with and without natural draft cooling towers and discuss the extent to which these effects might be mitigated by alternative cooling systems such as mechanical draft towers or a cooling pond.

Response

See response to preceding comment.

Comment 10-19

The protection of cultural resources has received only limited attention in the draft statement. We are particularly concerned about the possible impacts on three National Historic Landmarks shown on Table 2-16; they are: The Stony Point Battlefield, the Palisades Interstate Park and the Van Cortlandt Manor. In performing a more detailed analysis of impacts on these three historic sites, the State Historic Preservation Officer should be consulted along with local historical authorities, concerning the probability, character, and magnitude of impacts on all the sites identified. As indicated in paragraph 2.121, compliance with 36 CFR Part 800 appears to be warranted for at least three sites mentioned above. Further consultation with the State Historic Preservation Officer should confirm this.

Response

In the analysis presented in the DES, two potential sources of impact on historical resources are considered--acidic mists formed by the interaction of plumes from the stacks and cooling towers, if these are ultimately installed, and visual intrusion. On the basis of observations at operating natural draft cooling towers, the possibility of an increase in the incidence of fog and by inference, acidic mists, if these are formed at all, at ground level near the Bowline Point station is considered to be remote (paragraph 6.25 of the DES). Accordingly, it is not expected that damage to structures, including those of historical value, caused by corrosive airborne contaminants would be appreciably aggravated if evaporative cooling towers are installed. It may be well to note that recognition is given in the analysis to the contribution of the Bowline Point and Roseton generating stations to the formation of sulfate and nitrate aerosols and the attendant hazards of acid precipitation in the northern United States (paragraph 5.05 of the DES). Although the operation of these stations leads to no violations of applicable air quality standards.

Regarding the visibility of the power plants, the District has recognized the criterion of visual intrusion as one of the set of criteria identified by the U.S. Department of the Interior as pertinent in the determination of impact on historical resources (paragraphs 4.235 of the DES). Available analytical techniques to make such determinations, however, are limited and generally apply in predictive situations. In the case of the existing Bowline Point and Roseton generating stations, the District considers the revocation of its permits, forcing the abandonment and dismantling of the stations, as the only effective means of reducing possible visual impacts on historic sites in the vicinity of the stations. As stated in paragraph 6.01 of the DES, the District has considered this course of action and evidence of adverse impacts on historic sites is one of the factors entering into the District's final decision. No specific instance of damage to historic sites has been reported in comments to the DES.

Comment 10-20

Although there may have been previous ground disturbances in the area, we believe that the final statement should address the presence and protection as necessary, of archeological values that may be affected as a result of cooling tower construction. If these matters have not previously been considered at the proposed site of construction, they should be assessed at this time. The final statement should include the comments of the State Historic Preservation Officer and show compliance with 36 CFR Part 800.

Response

An archeological survey of the Bowline Point site has not been conducted. Accordingly, information needed to assess the potential for destroying archaeological values if cooling towers are constructed is not available to the District. The District has considered the requirement that an archaeological survey be conducted and that the necessary protection be provided as an additional condition to its permits covering the Bowline Point and Roseton Generating stations.

Comment 10-21

The discussion in paragraph 5.01, of adverse impacts on page 5-1 of the DES states that there is no reason to believe that the construction or operation of the Bowline and Roseton stations will affect groundwaters in their vicinity. We agree that the possibility of adverse impacts on groundwater are negligible since oil is being used as fuel. In the event of the conversion to coal, which appears to be unlikely, further analysis of groundwater impacts would be necessary. It is possible that the plant will be modified to use cooling towers under which conditions salt from the cooling tower drift may infiltrate the groundwater. The final statement should assess the potential for salt infiltration to the groundwater from this source.

Response

The maximum average deposition of salt at 0.2 mile of the proposed Bowline Point towers during the 1964-1965 drought would have been 39.5 kg/ha/yr (see paragraph 4.89). Salt deposition within 270 m of the ocean under a pine forest averaged 687.6 kg/ha/yr during a recent study (Potts, 1978). Because of this 17-fold difference and the presence of potable water at distances less than 270 m along oceanic coasts, the potential for adverse impact of salt to groundwater at Bowline Point is probably remote. The potential risk at Roseton is even lower due to substantially lower deposition rates than at Bowline Point (see paragraph 4.108).

STATE OF NEW YORK, DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Comment 13-1

To eliminate duplicative efforts, we suggest that the Army Corps of Engineers become a party to the on-going EPA adjudicatory hearings, or at least defer judgment on Bowline Point and other Hudson River power plants until EPA hearings have resolved the issue of close-cycle cooling.

Response

The Corps is preparing the EIS pursuant to the time requirements of a court approved schedule which is embodied in the Final Order. The court, in establishing its deadline, was aware of the ongoing EPA hearings dealing with closed cycle cooling, then in progress but did not link the Corps' obligation to file its final EIS on the progress or completion of those hearings. The recommendation contained in these comments is therefore in conflict with the Final Court Order, which imposes on the Corps a time limit with respect to filing the Final EIS. It should be noted, however, that the EIS has included in its discussion of the alternative of closed cycle cooling all information and data developed to data in the ongoing EPA adjudicatory hearings dealing with this subject.

Comment 13a-1

The consent decree directs the Corps of Engineers to prepare a draft EIS and circulate it for comments on the cumulative effects of Bowline Point Generating Station together with existing or proposed electric generating plants on the Hudson. A similar decree was issued for Roseton Generating Station. It is unclear whether the DES is designed to satisfy both decrees. The data for Bowline Point predominates, but discussion for the Roseton Plant also appear. We have reviewed the statement as pertaining to Bowline Point. It would be helpful to hear when a DES for Roseton is expected.

Response

The draft EIS was designed to consider the cumulative effects of existing or proposed electric generating stations on the Hudson River thereby satisfying the Consent Decrees issued for both Bowline Point and Roseton facilities. The decree issued for Roseton provided that the study and evaluation shall be based on information and data developed by the Corps or Engineers from the EIS prepared in connection with the operation of the Orange and Rockland plant at Bowline Point.

Comment 13a-2

The DES contains a clear explanation of the individual and cumulative thermal loads on the river due to once-through cooling. Yet the cumulative effects of other impacts such as noise, aesthetics, or salt drift from cooling towers are not consisely presented.

Response

Concern over the continued operation of the subject power plants with once-through cooling centers on their individual and combined effects on the aquatic ecosystem of the Hudson River estuary. Accordingly, this topic is prominent in the analysis presented in the DES.

Other potential sources of cumulative impacts, however, have not been overlooked. Among these are airborne-emissions of sulfur dioxide from the Bowline Point, Lovett, Roseton and Danskammer stations as well as possible interactions among the plumes from stacks and cooling towers, with the consequent formation of acidic mists. For reasons given in paragraphs 4.52 and 4.53 of the DES, the cumulative impacts of these stations on air quality in the study area are not expected to be appreciable.

There are presently no reported instances of citizens' complaints made as a result of noise generated at the power plants. Large structures such as power plants and cooling towers are at a rudimentary stage of development and means of deriving a succinct measure of cumulative visual impacts are not available. Such impacts are put into perspective in the DES by tracing the historic development of the Hudson River estuary (paragraphs 2.04 through 2.08) and relating the presence of the power plants on the river to that development (for example, paragraph 4.224 of the DES).

Comment 13a-3

Finally, the DES presents no recommended actions. There is no concluding summary which presents a preferred list of actions. The different alternative plans are not rated for their environmental impact. The reader receives no hint from the authors as to the solution which balances environmental impacts at Bowline Point. The Army Corps of Engineers has presented no proposal for Bowline Point Generating Station. A draft EIS should make some ordering of possible actions so that the reviewing agencies can best make comments to the Army Corps of Engineers. Therefore, the draft environmental statement should be redone incorporating the recommended actions and analysis supporting these recommendations. It should be reissued for comments after the Corps staff recommendations are incorporated into a draft statement, and after comments on this draft statement are received, a final environmental statement prepared and issued.

Response

The EIS was prepared to present several alternative actions related to the Corps of Engineers permit authorizing construction in navigable waters of the Hudson River of water intake structures forming part of the Bowline Point Generating Stations. Current regulations dealing with the preparation of the EIS do not require the Corps to rate the alternatives for their environmental impact. The data contained in the Final EIS will be utilized, however, by the Corps together with all other information contained in the administrative record in their decision affecting the modification, suspension or revocation of the existing permits.

what about upholding?

Comment 13a-4

The DES should compare the rate of flow in different parts of the intake train (Table 1-2) with the cruising speeds of fishes, such as Atlantic tomcod and striped bass, that are entrained and impinged at a high rate.

Response

The entrainment and impingement of striped bass and other fishes of the Hudson River are treated extensively in Chapter 4 of the DES. Noting the cruising speeds of these fishes and comparing these to the velocity of flow in various parts of the intake system is considered overly simplistic, possibly misleading and inappropriate in the section of the DES providing a description of the Bowline Point Generating station.

Comment 13a-5

The statement does not address the various methods by which these flow rates can be reduced to lessen impingement and entrainment losses during critical spawning or migration seasons.

Response

Such methods are discussed in detail in paragraphs 6.48 through 6.57 of the DES. An expanded section dealing with recent innovations in techniques designed to reduce damage at the water intakes of steam-electric power plants has been added to Chapter 6 of the FES.

Comment 13a-6

The construction of any of the cooling tower options, modifications of Bowline Pond inlet, dredging of Bowline Pond, or alterations of the intake or outflow will generate some amount of spoil. If a large volume of spoil is produced, then detailed evaluation of the impact of the disposal of the spoil is due including the location and ultimate disposition of the spoil. Additionally, the production of sediment during construction and its delivery in run-off to nearby water bodies should be addressed.

Response

Installing cooling towers at the Bowline Point station or implementing certain other alternatives to the present open cycle cooling systems would entail excavation work or dredging. Spoil would be generated in these operations and appropriate sites, either upland or at sea, would be needed for its disposal.

Comment 13a-7

Plants which will be subject to foliar injury from salt drift are not limited to the Orange and Rockland property as implied in the subsection of the DES beginning on pages 4-47, paragraph 4.80. Several critical areas will be exposed to increased airborne salt in the Hudson River Valley such as High Tor Mountain, Bear Mountain Park, and Harriman Park. A map and a more detailed description of the vegetation and critical areas potentially impacted by salt drift are needed.

Response

Only 11 plant species have been tested reliably for salt drift impacts. The distribution of these species and their potential to be damaged are discussed in paragraphs 4.85. The probability of other species being affected cannot be assessed due to a lack of information.

Comment 13a-8

In Section 2.81 of the DES, the discussion of effects on two species, the short-nose sturgeon (endangered) and the Atlantic sturgeon (threatened) is inadequate. Spawning and nursery areas are not mapped or described. Although this information is, in part, unknown, the DES does not hypothesize the likelihood of impact on these two important fish species.

Response

The existing populations of the two species of sturgeon are described in paragraph 2.81 (Endangered or Threatened Species) and the apparent effects of Hudson River power plants on sturgeon are addressed in paragraph 4. (impacts to Endangered or Threatened Species). These discussions have been expanded to include information in the testimony of W. Dovel (1979), which recently became available.

Comment 13a-9

Plants in the area are only identified and listed in paragraph 2.82, page 2-48 of the DES; no analysis on site or in the salt drift area appears. Experiments have shown Dogwood, a protected plant, to be a susceptible species to salt drift. Other protected plants may also be susceptible to salt drift.

Response

The salt drift impact assessment in the FEIS is the result of a site reconnaissance, literature critique, and computerized modeling of salt drift deposition. See paragraph 4.90 for specific species effects.

Comment 13a-10

The discussion of the physiography of the locale of the Bowline Point station contains no mention of the Ramapo Fault. The discussion should include some consideration of this feature.

Response

A reference to the Ramapo Fault has been added to discussion in paragraph 2.17. A more detailed discussion of this fault system may be found in Aggarwal and Sykes (1978).

Comment 13a-11

The probability of drought over the life of Bowline Point Generating Station is not addressed. Such climatological information is important in assessing possible impacts from salt drift.

Response

An analysis of salt drift during a drought year has been included in the FES.

Comment 13a-12

The oscillation of the salt wedge movement should be related to the likely increase in airborne salt in drift from the cooling towers.

Response

An expanded analysis of the salt drift including monthly variations in the deposition rate of salt, has been added to the FES.

Comment 13a-13

Discussions of adults, eggs, and larvae of the several species of fish occurring in Bowline Pond should include a comparison with fish in the open river and a record of abundance for a representative one-year period.

Response

The discussion of fish eggs, adults, and larvae in Bowline Pond and the Hudson River has been expanded in the FES and references provided for more detailed information.

Comment 13a-14

The data as presented in the thermal analysis and modeling section reflects sampling at specific times. A description which relates the frequency of occurrence of temperatures which exceed State and Federal standards would be helpful in understanding the expected thermal impact during the "worst case" situation.

Response

Additional information has been given in the revised analysis in the FEIS.

Comment 13a-15

The calculated total estimated loss of 70 cfs associated with the rejection of waste heat from all of the existing power plants on the Hudson River estuary, as discussed in paragraphs 4.23 through 4.26 of the DES, is indeed small when compared to 13,000 cfs, the average annual flow of the river at Green Island. However, the mean daily flow at Green Island drops to approximately 5,000 cfs during August in normal years and dropped to less than 3,000 cfs in August during the drought years of 1962-1964. Since Bowline Point is in an area of salt wedge dominance and draws brackish water most of the time, it is not expected to affect the movement of the salt wedge. However, the Roseton Plant may exert a greater influence, since it is further upstream. In addition, consideration should be given to the three proposed upstream stations, Greene County, Mid-Hudson, and Stuyvesant as well as to water withdrawn from the river by several municipalities, including the City of Poughkeepsie.

Response

As indicated in paragraph 4.24 of the DES, the District's estimate of the total loss of water due to the operation of existing power plants is considered to be an upper or conservative value. Further, flows gaged at Green Island represent the major portion but not the entire flow of freshwater into the Hudson River downstream of its confluence with the Mohawk River (paragraphs 2.25 through 2.28)

For these reasons, the estimated evaporative consumption of 70 cubic feet per second compared to an annual average flow of 13,000 cubic feet per second gaged at Green Island is expected to have a negligible effect in terms of the systematic, year-round movement of the salt wedge in the estuary. During years of normal or above normal flow, the salt front reaches the Bowline Point, Lovett and Indian Point stations at approximately mile point 40 in summer and fall, but does not reach the Roseton and Danskammer stations at approximately mile point 60 (paragraph 2.31 of the DES). During periods of abnormally low flow, the salt front moves to the Roseton and Danskammer stations and beyond, reaching as far as Hyde Park at approximately mile point 80 in the drought year of 1964. Thus, in normal years, an evaporative loss of freshwater amounting to 20 cubic feet per second due to the operation of the Roseton and Danskammer stations (paragraph 4.24 of the DES) might be compared to a flow of 5,000 cubic feet per second gaged at Green Island. In years of very low flow or severe drought, practically all of the estimated total evaporative loss of 70 cubic feet per second would be from brackish water. It is conceivable, however, that in intermediate situations the loss of 20 cubic feet of freshwater per second in the vicinity of the Roseton station could give rise to slight perturbations in the movement of the salt front.

With respect to possible future power plants on the river, the District recognizes that there would be a limit to the additional waste heat that could be accomodated without appreciably affecting the movement of the salt front or other hydrologic characteristics of the river or substantially depleting the freshwater resource (paragraph 4.26 of the DES). When this limit would be reached is unknown. Similarly, estimates of total withdrawals of water from the Hudson River by municipalities and industry is presently unknown. Regardless of whether or not these withdrawals have an appreciable effect on the movement of the salt front, it is clear that the added consumption of water caused by the operation of the power plants would make a small cumulative contribution to this effect for the reasons detailed above.

Comment 13a-16

Total settleable particulate deposition is presented on an annual basis in sections 4.49 through 4.72 of the DES. To be comparable with New York Ambient Air Quality Standards, monthly settleable particulate deposition should be presented.

Response

Reference is made in this comment to an extensive portion of the DES and it is difficult to pinpoint the specific instances in which annually-averaged deposition rates for settleable particulates are quoted in place of more useful values derived from averages taken over shorter intervals of time.

Comment 13a-17

Maximum predicted deposition for salt alone should have been presented for the critical months of July, August and September when river salinity is highest.

Response

A more extensive and detailed analysis of salt drift and the attendant deposition of salt is given in the FES. Monthly values of the deposition are given in the expanded analysis.

Comment 13a-18

It is stated in section 4.53 of the DES that merging of the cooling tower and stack plumes would occur frequently but no specific details of the orientations of the stack and proposed cooling towers with respect to the prevailing wind directions are given. Conflicting reports from plants with operating cooling towers exist with respect to increased acidity of rainfall or drift. While the authors do not expect this effect "to be appreciable," perhaps the degree of impact can be further refined.

Response

As stated in section 4.53 of the DES, knowledge of the physical and chemical phenomena leading to the formation of acidic mists in merged plumes is incomplete. There are, at present, no means of predicting either the frequency at which the plumes might interact or the extent and severity of the impacts associated with these interactions. Such potential effects are not expected to be appreciable in view of the paucity of evidence pointing to significant problems at fossil-fueled power plants equipped with evaporative cooling towers.

Comment 13a-19

The phenomenom of salt draft is treated in Sections 4.64 and 4.65 of the DES as a temporary condition that occurs only intermittently. Although the concentration of salt will vary, the exposure will be continual. Rain may provide some relief by rinsing the vegetation from external salt deposits. A 30 to 40 year exposure to salt-laden air may cause permanent changes in the vegetation. The final EIS should reflect this condition.

Response

An expanded analysis of salt drift and deposition is included in the FES.

Comment 13a-20

Maps of the Bowline Point and Roseton areas, with isoplethes to indicate salt concentrations and deposition rates, would assist in understanding how the analysis of salt drifts relates to the site. A map that translates the amount of salt deposition to the degree of expected damage to susceptable plant species would be helpful in assessing the adverse environmental impact of salt drift on vegetation.

Response

To the greatest extent possible, these suggestions are incorporated in the expanded analysis of salt drift presented in the FES.

Comment 13a-21

Requirements to replace specimens injured by salt drift (see page 4-47, paragraphs 4.81-4.85 of the DES) or plans for rinsing deposited salt off susceptible foliage should be discussed in the Final EIS.

Response

Replacement of injured species has been discussed for Comment 1-2. Rinsing deposited salt is theoretically possible but probably impractical since deposition on each plant would have to be continually monitored to determine when the no-visible-effect level would be attained.

Comment 13a-22

It may be more significant to analyze the impact of the Bowline and Roseton stations in relation to other Hudson River generating stations in the region. While the DES reviews such work, it draws no conclusions. The statement should note whether a course of action for Bowline Point and Roseton should be determined by analyzing the impact of each station individually or a comparison of all generating facilities within the region. It should also note whether an individual species analysis, as is presented for striped bass, is important in the analysis of impact. As this section stands, it is only a summary of literature, not a statement of analysis.

Response

The determination of a course of action concerning the Bowline and Roseton Generating Stations will be made based on impacts due to each station individually as well as the combined impacts of all power stations operating on the Hudson River. An environmental impact statement is an environmental disclosure document, the purpose of which is to contribute environmental information to the decision making process. An impact statement is not the decision document itself. Corps regulations specifically require that a course of action regarding permit applications cannot be announced until at least 30 days after release of the final environmental impact statement. The District disagrees with the statement that the DES is not an analysis of impacts.

Comment 13a-23

The section of the DES beginning on page 4-47, paragraphs 4.81-4.85 has a inadequate description of salt drift impacts. The air quality section (pp. 4-27 through 4-31) is not explicit in its estimation of the likelihood and location of salt deposition. An analysis of the expected impacts is not given in either section. Three susceptible species are listed; of these, flowering dogwood, is a protected native plant.

Response

The DEIS discussions have been replaced with the only reliable information available concerning salt drift effects (see paragraphs 4.102). Flowering dogwood probably would not be visibly, acutely affected during a drought such as 1964-5.

Comment 13a-24

Mitigation measures for foliage injured by salt drift are not discussed in the section of the DES beginning on page 4-47, paragraphs 4.81-4.85. The following issues should be addressed in the Final EIS:

- replacement costs for injured plants,
- agent responsible for plant replacement, and
- long-term impacts to vegetation.

Response

Since the potential effects of salt drift to plants can be assessed for only 11 species, an estimate of replacement costs would not be reliable. The designation of parties responsible for environmental damage costs is not a function of an environmental impact state. Long-term drift imapcts to vegetation are not known. (see paragraph 4.).

Comment 13a-25

On page 4-49, paragraph 4.88 of the DES, the statement summarizes that the cumulative impact on upland ecosystem from salt drift will be similar among the various Hudson River power plants. Furthermore, the statement indicates that, "the overall land area devoted to power plants would be a small percentage of the total land area of the Hudson River Valley." The authors oversimplify the situation.

Response

The DEIS discussion on page 4-47 has been deleted since cumulative salt drift impacts cannot be properly assessed due to a lack of sufficient information.

Comment 13a-26

Since impingement losses at Bowline are greatest between October and April, and coincide with the lowest thermal loads on the river, perhaps a scheme of reduced pumping would alleviate impingement losses. The statement does not seem to try and correlate the different impacts with respect to season or overall thermal conditions in the river.

Response

Problems associated with this alternative are discussed in Chapter 6 of the FES beginning at paragraph 6.69 .

Comment 13a-27

In the DES, paragraph 4.116, entitled Fish Impingement, the analyses relies heavily on impact to striped bass. An attempt to better assess the adverse impacts on other species should be made.

Response

The Bowline fish impingement section has been rewritten for the FES. The revised section discusses impacts to other species of fish including white perch, blueback herring, rainbow smelt, alewife, bay anchovy, and Atlantic tomcod.

Comment 13a-28

The alternatives to the present once-through cooling system are not presented in any detail. Natural draft cooling towers are described but a detailed comparison of relative impacts is lacking. The individual and cumulative effects of, for example, increased icing and fogging, increased and mortality, evaporative losses on river flow regime and blowdown discharges are not compared to the adverse impacts of once-through cooling. The alternatives to natural draft cooling towers are presented cursorily and, seemingly, without seriousness.

Response

As indicated in paragraph 1.61 of the DES, the U.S. Environmental Protection Agency is requiring, through the provisions of the National Pollutant Discharge Elimination System (NPDES) programs, that closed cycle-cooling systems be backfitted to the Bowline Point and to the other eligible power plants on the Hudson River. These requirements are being contest by the utility companies involved and an adjudicatory hearing on the matter is currently in progress before the Environmental Protection Agency. Decisions on whether and at which facilities closed-cycle cooling systems will be required, will be made by the Environmental Protection Agency.

Accordingly, the District has assessed the impacts associated with the Bowline Point and Roseton stations operating both with open-cycle and closed-cycle cooling systems as well as the cumulative impacts of closed-cycle cooling systems at all of the eligible plants on the Hudson River. This situation would prevail in the long term if the Environmental Protection Agency's present requirements ultimately remain in effect and if the District maintains its present permits and conditions relating to the subject power plants. A number of closed cycle cooling alternatives are considered in this context (paragraphs 6.10 through 6.64 of the DES) since decisions on the specific type of cooling system to be installed at each of the eligible power plants have not been made to date. The objective of this portion of the District's analysis is to emcompass the range of possible impacts associated with closed-cycle cooling and to focus on the pertinent characteristics of each alternative system that appears practical. In this manner, the District has considered the outcome of some of the alternative options relating to the continued operation of the Bowline Point and Roseton generating stations.

There is no intent on the part of the District to provide a detailed analysis on which to base the choice of a particular type of closed-cycle cooling system as best suited for the Bowline Point Station. Such an analysis would require information that has not been developed to date. Orange and Rockland has identified natural draft evaporative cooling towers as the preferred closed-cycle cooling alternative and have prepared technical design documents for a proposed system (Orange and Rockland, 1974a; 1977).

On the basis of this design, the District has made estimates of the environmental impacts that may be expected to result from the installation of a natural draft cooling system as well as comparisons of these impacts with the impacts associated with practical alternative systems (Chapters 4 and 6 of the DES and FES). Underlying this assessment and comparative analysis are general considerations and findings reported in the literature, generally applicable rules of thumb and parallels drawn, wherever appropriate, from an analysis related to cooling alternatives at Unit 2 of the Indian Point station (U.S. Nuclear Regulatory Commission, 1976). It may be anticipated that more detailed analyses on alternative cooling systems and their environmental impacts will be submitted by Orange and Rockland to the District when the company submits an application for the permits necessary to construct a closed-cycle cooling system. An environmental assessment of the various alternatives would be made at that time.

Comment 13a-29

A comparison of the icing and fogging of the cooling tower alternatives in the Bowline Point vicinity should be added to paragraphs 6.24 through 6.26 of the DES.

Response

Paragraphs 6.24 through 6.25 of the DES deal with the atmospheric effects associated with evaporative material draft cooling towers. Information is given in these paragraphs to support the District's conclusion that fogging and icing resulting from the operation of natural draft towers at the Bowline Point stations are not expected to pose any significant problem. In the case of mechanical draft cooling towers, it may be anticipated that the atmospheric effects resulting from the release of warm moist air relatively close to ground level would be more pronounced, as indicated in paragraphs 6.37 and 6.38 of the DES. On the basis of operating experience reported in the literature and an analysis of alternative closed-cycle cooling alternatives for Unit 2 of the Indian Point generating station (U.S. Nuclear Regulatory Commission, 1976). Light friable ice is expected to form in the vicinity of the cooling towers under certain meteorological conditions and in most instances, fogging and icing are expected to be confined to distances of 1,000 to 2,000 feet from the towers. Experience with spray cooling ponds is more limited. Drift generated by the spray modules is substantial and an application of this type of cooling system in Bowline Pond would require a careful design to avoid creating a problem in the residential neighborhoods close to the power plant. As indicated in paragraph 6.42 of the DES, the District estimates on the basis of available information that a buffer zone of 1,000 to 1,500 feet would be needed to confine fogging and drift from the spray cooling modules to the site.

Comment 13a-30

The cooling pond alternative (paragraphs 6.40 through 6.42 of the DES is routinely mentioned and dismissed without an explanation of why this alternative is not feasible. A more detailed discussion of this and other alternatives should be included.

Response

A cooling pond at the Bowline Point generating station is considered impractical because of the inordinate land requirements, estimated to by 750 acres (paragraph 6.40 of the DES). This requirement could be reduced by a factor of approximately 20 by the introduction of spray modules so that the existing Bowline Pond could, in principle, serve as a closed-cycle cooling system (paragraph 6.42). However, the several factors discussed in paragraphs 6.41 and 6.42 of the DES must be considered in greater detail before a final judgement can be made as to the practicality or advisability of installing spray modules in the Bowline Point.

As indicated in response to a previous comment, all of the alternatives discussed in the DES are considered on the basis of available information and in detail deemed sufficient in relation to the District's responsibilities under the National Environmental Policy Act.

Comment 13a-31

The proposed rescheduling of plant operation, discussed in paragraphs 6.48 through 6.57 of the DES, seems to be a legitimate proposal, regardless of the ultimate decision (regarding the need for a closed-cycle cooling system). The plant could be scheduled, in synchrony with others, so that entrainment and impingement losses are diminished during the construction of cooling tower, cooling pond, or other structural modifications which may be mandated. This concept has value and should be pursued during the interim period of construction. However, this alternative is presented superficially and without an assessment of its impact on feasibility.

Response

Various restrictions that might be imposed on the operation of the Bowline Point generating station are discussed in broad terms in paragraphs 6.48 through 6.57 of the DES. For reasons mentioned throughout this section, it is impossible without further analysis and information to determine the potential effectiveness of these restrictions with respect to the aquatic ecosystem of the Hudson River. As indicated in the DES, a modified schedule of operation of the Bowline Point station, possibly as part of a comprehensive management program within the New York Power Pool (paragraphs 6.61 and 6.62 of the DES) or in combination with other protective measures, may be an alternative to closed-cycle cooling that is deemed acceptable by the U.S. Environmental Protection Agency. If this is not the case, restrictions on the operation of the power plant may prove to be sufficiently attractive to warrant the imposition of such restrictions while a closed-cycle cooling system is under construction, or indeed, in operation. Careful consideration will be given by the District to the possibility of improving conditions related to the operation of the power plant at the time an application is made by Orange and Rockland to secure the permits necessary to construct a closed-cycle cooling system at the Bowline Point station.

Comment 13a-32

A variety of modifications to the intake structure are mentioned but not analyzed in paragraphs 6.58 through 6.60 of the DES. It is difficult to review these proposals without a description of the possible effects in minimizing losses or the feasibility of construction.

Response

An expanded section on possible improvements to the power plant intake structure is provided in the FES. Included in this discussion are several modifications that are considered to be technically feasible and projections that can soundly be made regarding their potential effectiveness. As stated in the DES, the District regards these modifications as alternatives to closed cycle-cooling, any one of which may prove to be acceptable to the U.S. Environmental Protection Agency.

Comment 13a-33

The above proposals in Section 6 may be valuable and realistic alternatives to once-through cooling or cooling towers. Yet, no in-depth analysis appears in the DES. The ultimate decision for the cooling system at Bowline Point must consider these alternatives. The incorporation of these methods may preclude the necessity of a cooling tower; thus, impingement and entrainment losses will be reduced without introducing folair damage from salt drift, increasing icing and fogging, noise pollution, aesthetic degredation, and addition consumptive water use which are coincident with cooling towers.

Response

Responses to previous comments elucidate the context in which the District has analyzed the possible alternatives to closed-cycle cooling.

Comment 13a-34

In a letter referred to on page B-5 of Appendix B-1, the Army Corps of Engineers recommended that Bowline Point Generating Station "be placed on a last-on, first-off method of operation to minimize the use of the plant during spawning seasons of striped bass." The authors should repeat this recommendation in its section on alternatives to cooling towers, instead of burying it in an appendix.

Response

The "last-on-first-off" mode of operation is described in paragraph 6.55 of the DES and considered together with other operational restrictions in paragraphs 6.48 through 6.57 of the DES.

Comment 13a-35

The comparison of capability losses and costs of two different cooling towers done by the utility is found in an appendix. Such a discussion should appear in Section 6, the section which deals with alternative actions, with a comment from the authors in regard to the realiability of such figures. This valuable information should not appear only as a reference in an appendix.

Response

An analysis of the monetary costs associated with a natural draft evaporative cooling system for the Bowline Point station is given in paragraphs 6.29 through 6.32 of the DES. Under present conditions of high energy costs, differences in the overall economics of natural and mechanical draft systems are expected to be marginal or slightly in favor of the natural draft systems. Differences in the loss of capability are small and result from an optimization in balancing capital costs against operation and maintenance costs.

STATE OF NEW YORK, METROPOLITAN TRANSPORTATION AUTHORITY

Comment 15-1

The Draft Environmental Statement appears to support the use of cooling towers as part of the condensor system. We would like to point out that there is considerable controversy about the overall effectiveness of such towers in reducing environmental impacts. In addition, there is no doubt that the energy efficiency of the power plant will be reduced by the use of the towers.

Response

The impact of salt drift from cooling towers at Bowline and Roseton is discussed in the FES beginning at paragraph 4.85 . The effect of cooling towers on power plant efficiency is discussed beginning at paragraph 6.18 .

CENTRAL HUDSON GAS AND ELECTRIC CORPORATION

Comment Letter 16

In this letter it is stated that:

- the Corps cannot alter the permit as presently in effect.
- the Draft Environmental Impact Statement exceeds the terms of the Consent Decree as it relates to the Roseton Generating Station.

Response

To the extent that the comments question the Corps' responsibility to prepare the EIS, the Final Order issued by the court mandates that the Final EIS be filed by a date certain. During the course of the litigation, arguments were made that the Corps should not be required to complete the EIS in view of the pendency of the EPA adjudicatory hearings. Notwithstanding, the Corps was ordered to proceed with and complete the filing of the Final EIS. To the extent that the comments suggest limiting the scope of the EIS, they are clearly inappropriate to current regulation and policy, which require the EIS to include a sufficiently broad discussion of connected actions, cumulative actions and similar actions. The discussion of alternatives should address the no-action alternative, other reasonable courses of actions and mitigation measures as well as impacts that may be direct, indirect or cumulative.

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

Comment 17-1

In the Draft Environmental Statement (DES) for Bowline, the Corps has considered four alternative actions, but has not yet selected one of them. We urge that the first contention of the present permit, be adopted. Selection of this option would essentially preserve two of the other options as well, since it recognizes that a final determination with respect to cooling systems, plant intakes, and operations of the Hudson River power plants will result from the current proceedings pursuant to the Federal Water Pollution Control Act (FWPCA).

Response

This comment relates to the ultimate action which may be taken by the Corps with respect to modification of the existing permit, and not to the preparation of the EIS. As such, the comment is noted.

Comment 17-2

Clearly, the Corps should avoid duplication of effort and leave to the agency authorized by the FWPCA the task of setting limitations applicable to the cooling water systems of the power plants in question. That agency will have the opportunity to consider and evaluate the voluminous record of ecological studies and analyses being produced in this case, and reach a reasoned decision on what remedial action, if any, need be taken. In adopting final determinations since proceedings pursuant to FWPCA are already underway, with testimony having been submitted by the utilities in July 1977, and hearings scheduled to start on December 6, 1977. Indeed we believe that Section 101(f) of FWPCA, if it means anything at all, means that the Corps should defer to the FWPCA proceedings in the circumstances of the Hudson River power plants.

Response

The Corps is preparing the EIS pursuant to a court approved schedule. The court, in approving the deadline, was aware of the ongoing EPA hearings on closed cycle cooling which were in progress or completion of those hearings. The recommendation contained in this comment, therefore, is in conflict with the Final Order, which imposes on the Corps a time limit with respect to filing the Final EIS. It should be noted that these hearings commended in 1977 and, at this point, are open-ended. It further should be noted that the EIS has included in its discussion of the alternative of closed cycle cooling all information developed to date from the ongoing EPA administrative hearings dealing with this subject.

Comment 17-3

We believe the Corps should defer to the FWPCA proceeding for the ultimate determination of the cooling system for Bowline. However, if the Corps intends to act on its own pursuant to NEPA, this DES is an inadequate basis for such action. No analysis of the relative costs and benefits of alternative actions, including various mitigating measures is presented. The Corps has not presented such an analysis, nor has it evern summarized the factors that must be weighed in this case or attempted a qualitative balancing.

Response

The Corps is required to utilize a systematic interdisciplinary approach which will ensure the integrated use of the natural and social sciences in planning and decision making. To this end the EIS has included a detailed discussion of the following:

1. The environmental impact of the proposed action.

2. Any adverse environmental effects which cannot be avoided should the proposal be implemented.

3. Alternatives to the proposed action.

4. The relationship between short term uses of man's environment and the maintenance and enhancement of long term productivity.

5. Any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

ORANGE AND ROCKLAND UTILITIES, INC.

Comment Letter 18

In this letter, the jurisdiction of Corps of Engineers to compel changes in operating conditions of any existing power plants on the Hudson River is questioned and that the alternatives available to the Corps is limited.

Response

To the extent that the comments question the Corps' responsibility to prepare the EIS, the Final Order issued by the court mandates that the Final EIS be filed by a date certain. During the course of the litigation, arguments were made that the Corps should not be required to complete the EIS in view of the pendency of the EPA adjudicatory hearings. Notwithstanding, the Corps was ordered to proceed with and complete the filing of the Final EIS. To the extent that the comments suggest limiting the scope of the EIS, they are clearly inapposite current regulations and policy, which require the EIS to include a sufficiently broad discussion of connected actions, cumulative actions and similar actions. The discussion of alternatives should address the no-action alternative other reasonable courses of actions and mitigation measures, as well as impacts that may be direct, indirect, or cumulative.

COMBINED TECHNICAL COMMENTS BY: CENTRAL HUDSON GAS AND ELECTRIC CORPORATION, CONSOLIDATED EDISON COMPANY OF NEW YORK, INC., ORANGE AND ROCKLAND UTILITIES, INC., AND THE POWER AUTHORITY OF THE STATE OF NEW YORK

Comment 19-1

Paragraph 1.07 of the DES does not indicate that the Calspan Corporation prepared a Draft Environmental Impact Statement which was submitted to the Council on Environmental Quality on August 23, 1974.

Response

A footnote to Paragraph 1.07 of the DES has been revised to show that a draft environmental statement relating to the Bowline Point Station was prepared and submitted to the Council on Environmental Quality on 23 August 1974.

Comment 19-2

A clear photograph showing the Bowline Plant and its relationship to its surroundings should be used in place of Figure 1-1.

Response

Figure 1-1 of the DES has been upgraded to show a clearer photograph of the Bowline Point Generating Station. An artist's impression providing an indication of the visual dominance of natural draft cooling towers at the Bowline Point Station is shown in Figure 4-14 of the DES.

Comment 19-3

It is noted that conditions relating to closed-cycle cooling at Bowline are being contested in an EPA adjudicatory hearing.

Response

A note to this effect has been added to paragraph 1.61.

Comment 19-4

Paragraph 1.61 improperly assumes that Section 326(b) of the Federal Water Pollution Control Act automatically requires closed-cycle cooling.

Response

Paragraph 1.61 has been revised to clarify the relationship between the requirement to backfit closed cycle cooling at certain older plants on the Hudson River and the provisions of Section 316(a) and (b) of the Federal Water Pollution Control Act Amendment of 1972.

Comment 19-5

Referring to Table 1-4, NRC licenses now call for cessation of once-through cooling operation by May 1, 1982 for Indian Point Unit 2 and September 15, 1982 for Indian Point Unit 3. Footnote 2 erroneously states the utility's present share of the Roseton Plant's capability.

Response

The information contained in Table 1-4 of the DES is taken principally from the New York Power Pool's annual report published in 1976 (New York Power Pool, 1976). Later editions of the report indicate that certain specific details no longer apply. Table 1-4 has been updated on the basis of information given in the Power Pool's report published in 1979 (New York Power Pool, 1979).

Comment 19-6

The discussion in Chapter 1 of the DES on other major projects on the lower Hudson River should examine more recent reports providing details of the overall planning in the area.

Response

Much of the information underlying the positions of the DES dealing with the characteristics of power plants on the Hudson River is taken from the New York Power Pool's annual report published in 1976 (new York Power Pool, 1976), the latest edition of the report available during the preparation of the DES. Changes in the long range plans of the member electric systems of the Power Pool have been made and reported in subsequent editions of the report. Where these changes bear on matters addressed specifically in comments on the DES or could materially affect the analysis contained on the DES, updated information is provided in FES. Among the sources of this information is the Power Pool's report published in 1979 (New York Power Pool, 1979), the latest edition presently available.

Comment 19-7

A number of corrections were provided by the Commenter concerning the capacity and other characteristics of present or planned power plants.

Response

The suggested amendments have been made wherever appropriate.

Comment 19-8

The Hudson River is a partially-mixed estuary, rather than the well-mixed estuary referred to in Paragraph 2.29 of the DES.

Response

Appropriate changes have been made in the text of the DES.

Comment 19-9

In paragraph 2.31, a definition of "normal" lower Hudson River freshwater flow should be provided.

Response

Appropriate amendments have been made in the text of the DES.

Comment 19-10

The utilities disagree with the statement in Paragraph 2.38 of the DES that the artificial thermal load imposed on the Hudson River raises the temperature of the receiving waters appreciably. The increase is not biologically significant relative to natural temperature fluctuations.

Response

Appropriate amendments have been made to the text of the DES.

Comment 19-11

The predominant animal list in the section in Chapter 2 on Upland Ecosystems in the DES should include the ruffed grouse, red fox, and gray fox. The quail should probably be eliminated from the group.

Response

The text beginning at paragraph 2.54 has been changed to reflect this comment.

Comment 19-12

Any species data collected by the N.Y.S. Department of Environmental Conservation in 1972 (see DES paragraph 2.57) should be presented here since the composition of the marsh might have changed between 1951 and 1972.

Response

Comment noted.

Comment 19-13

Figure 2-13 of the DES, Simplified Aquatic Food Web near Bowline Point, is somewhat misleading in that detritus also contributes to the base of the food web, along with primary producers.

Response

Modifications have been made to Figure 2-13 to show energy flow from detritus to the food web through bacteria.

Comment 19-14

Contrary to the statement made in DES paragraph 2.63, zooplankton concentrations were found to be highest in the Kingston area, not in the low to mid-salinity portions of the estuary.

Response

Paragraph 2. 65of the FES has been chanaged to include this information.

Comment 19-15

As stated in Paragraph 2.64 of the DES, copepods are certainly a dominant zooplankton species in the Hudson River estuary. However, unless copepod nauplii are included in this statement, other forms such as rotifers may predominate. (Orange and Rockland, 1977; Section 7.1.3.1.1).

Response

Under the assumption that to "predominate" is defined as dominance of numbers, then it is true that the recent study by Orange and Rockland (1977) shows that rotifers may at times predominate over copepods (exclusive of copepod nauplii). The text of Paragraph 2.64 in the FES has been changed accordingly.

Comment 19-16

Pertaining to Paragraph 2.66 of the DES, vertical migration patterns have been clearly demonstrated in macrozooplankton forms in the Hudson River, but this statement is questionable for most microzooplankton.

Response

The text of paragraph 2.66 of the FES has been revised to reflect this comment.

Comment 19-17

Pertaining to Paragraph 2.69 of the DES, evaluation of data subsequent to earlier reports has shown that the benthic community structure in the Bowline vicinity is not stable, but rather subject to yearly as well as seasonal variation. (Orange and Rockland, 1977; Section 8.1.3.3.1.1, p. 8.1.-102).

Oftentimes, the dominant organism is Amnicola rather than annelid worms. (Orange and Rockland, 1977a; Section 8.1.3.3.1.1, p. 8.1-118).

Response

The text of Paragraph 2.93 of the FES has been revised to reflect this comment.

Comment 19-18

The statement made in Paragraph 2.69 and 2.70 of the DES that the amphipod Gammarus is the dominant fish food in the Hudson River estuary is not necessarily true. Food preference or consumption depends on species, size, and season as demonstrated in Orange and Rockland, 1977; p. 10.1-125 for white perch, p. 10.1-157 for striped bass and p. 10.1-202 for Atlantic tomcod. Copepods and dipterans dominate the stomach contents during certain seasons.

Response

The text of Paragraph 2.72 of the FES has been revised to reflect this comment.

Comment 19-19

The bay anchovy spawns not only in mid-salinity regions of the Hudson, but also in saline waters along the Atlantic coast (Paragraph 2.74 of the DES).

Response

The text of paragraph 2. 74 of the FEIS has been revised to reflect this comment.

Comment 19-20

The evidence is that the larvae of fish are not simply carried downstream after hatching as suggested in paragraph 2.75 of the DES. The true phenomenon is much more complex than simple transport by currents.

Response

The text of Paragraph 2.75 of the FES has been revised to reflect this comment.

Comment 19-21

Striped bass have been omitted from the discussion of the lower Hudson River fishery in Paragraph 2.77 of the DES.

Response

Striped bass have been added to the discussion of the lower river fishery in Paragraph 2. 77 of the FES.

Comment 19-22

The statement: "Sport fishing is also an important use of the Hudson River's fishery resource," in Paragraph 2.79 of the DES is unsupportable; the implication that the Hudson River is the major contributor to sport fishing in the North Atlantic and New England Regions is incorrect. Estimates of contribution of Hudson River striped bass to Long Island Sound and the mid-Atlantic fishery are provided in McFadden (1977) at Section 7.10.7.

Response

Paragraph 2.79 has been modified in accordance with this comment. Although the Hudson River is not "the major contributor" to striped bass standing stock in the North Atlantic, the Hudson may provide spawning and nursery grounds for a substantial portion (up to 30 percent) of the fishery. Data cited in McFadden (1977) also shows that Hudson River stock composes the majority of sub-legal size striped bass collected in the vicinity of western Long Island. Further studies are required to define adequately the contribution of Hudson River striped bass stock to the Atlantic Coast population.

Nb

Comment 19-23

In reference to Paragraph 2.82 of the DES, the flowering dogwood is a protected species of plant in New York State. It is illegal to disturb this species in its natural environment. As a result of operation of a natural draft cooling tower, the dogwoods may be damaged by salt drift.

Response

This comment is addressed in a revised section on cooling tower drift and salt deposition beginning at Paragraph 4.85 of the FES.

Comment 19-24

Table 2-10 of the DES (Endangered, Extirpated, and Extinct Wildlife of New York State) should be confined to species which have been found or are likely to use the Hudson Valley. As it is, it gives the impression that many species could possibly be affected by development along the Hudson.

Response

Paragraph 2.80 of the FES, Endangered or Threatened Species, states that of the animals legally considered threatened or endangered in the State of New York, the Atlantic sturgeon and shortnose sturgeon are most likely to be affected by the power plant.

Comment 19-25

A more detailed discussion of the aquatic ecosystems in the Bowline and Roseton vicinities than presented in Paragraphs 2.86 to 2.109 of the DES may be found in Orange and Rockland (1977a) and Central Hudson (1977a) Section 6.1, 7.1, 8.1, 9.1, and 10.1.

Response

The description of aquatic ecosystems given in Chapter 2 has been modified and expanded as appropriate.

Comment 19-26

In addition to the effects of salinity changes mentioned in Paragraph 2.90 of the DES, seasonal succession of microzooplankton species is also linked to temperature and possibly to nutrients. Even if salinity were held constant, a seasonal pattern of species would occur.

Response

The text of Paragraph 2.90 of the FES has been revised to reflect this comment.

Comment 19-27

The definition of a "major consumer" of Hudson River water in Paragraph 3.21 of the DES should be clarified. Simply heating water does not consume it.

Response

As discussed in paragraph 4.23 of the DES, the rejection of waste heat from a power plant operating with open-cycle cooling promotes evaporation at a rate greater than would naturally prevail and effectively constitutes a consumptive use of water. In the case of the existing power plants on the Hudson River Estuary, this consumption is estimated to be of the order of 70 cubic feet per second, or 50 million gallons per day, on the basis of a rule of thumb provided by the U.S. Environmental Protection Agency (paragraph 4.24). An aggregate consumption of such magnitude is sufficient to support the statement that the power plants are major users of water.

Comment 19-28

Contrary to Paragraph 4.03 of the DES, it is unlikely that the Bowline Plant affects the flow regime of the estuary. All data indicate that its influence is not felt even over one-quarter of the river width.

Response

Paragraph 4.03 of the DES is an introductory statement listing the potential effects that the continued operation of the Bowline Point Generating Station might exert on the physical resources of the Hudson River Estuary. Each of these potential effects is treated as a cause of concern and is examined in subsequent portions of the DES. With respect to alteration in the flow regime of the estuary, the statement is made in Paragraph 4.26 of the DES that the effects associated with the rejection of waste heat from all of the existing power plants on the Hudson River are considered to be negligible.

Note

Comment 19-29

Not all proposed plants were included in the thermal model, nor should they be. (See comments on paragraph 4.14, below.)

Response

The comment includes the required response.

Comment 19-30

The near-field analyses have included recirculation considerations. (See McFadden, 1977, at Section 8.3.3 and Orange and Rockland, 1977a, at Section 3.1.3.3.3.)

Response

Thermal impact of the multiple-power-plant-operation on the Hudson River cannot be based on a near-field analysis which includes

solely

only a simplistic formulation of the recirculation effect. Considering the ~~tidal-dominated~~ flow conditions in the estuary, and the proximity of the locations of the major power plants, the thermal impact of the multiple-power-plants operation on the receiving waterbody of the estuary depends on (1) reentrainment, (2) recirculation, and (3) thermal interaction among the different power plants. Detailed discussions of these important effects are presented ~~in Appendix E~~ of the DEIS (Sec. 3.5.1) and also in Appendix E of the FEIS (Sect. 2.1). A relatively simple ~~but~~ correct formulation of the ~~reentrainment and~~ recirculation effects, under reversing flow conditions, is presented in Assessment of Technique, for hydrothermal prediction, by G. H. Jirka, G. Abraham and D. R. F. Harlemann (Sec. 8.3), Report No. 203, Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, MIT, July 1975.

Comment 19-31

The statement is made that natural conditions cannot be ascertained from field measurements. A good estimate of natural conditions can be made from measurements. The important question is how precise need the estimate be for impact assessment.

Response

The statement in Appendix E of the DEIS, "The situation in the Hudson River is such that the zones of thermal influence of the existing power plants overlap, making it impossible to ascertain through measurements alone the degree to which natural conditions are altered by each individual plant," is correct. The statement of the comment "a good estimate of natural conditions can be made from measurements" is wrong as long as power plants continue to operate during the measurements. The natural thermal conditions (ambient conditions), consistent with the statement of the state thermal standards as "before the addition of heat of artificial origin," can be determined based on field-measured water temperature data only if all the plants are shut down for a sufficiently long time period (more than a month). The statement of the comment "the important questions is how precise need the estimate be for impact assessment" is immaterial and indicates a lack of understanding of the hydrothermal phenomena which control the thermal impact of multiple-power-plant-operation on the Hudson River.

Comment 19-32

Statistical analysis of the thermal field study results used to obtain the 2 to 6 dilution indicate that the frequency of occurrence of excess surface temperatures of 7.5 is less than 1 percent and that 50 percent of the time, the maximum excess surface temperature of the time, the maximum excess surface temperature is about 4°F. Further, although dilution ratios of 6 to 9 were computed by the ORNL Model (Table 3.3.1, Appendix E), these values were not used here to assess the thermal effects.

Response

The results obtained in Sect. 3.3.1, Appendix E are strictly for the "Near-Field Analysis of Thermal Discharges" as indicated in the title of the section. The results based on the dilution ratios 2 - 6 cannot be utilized alone to determine the thermal impact of power plant operations on the Hudson River, since these models do not include any of the controlling hydrothermal phenomena in the estuary, consisting of (1) the reentrainment of the heated water at the discharge(s) of a power plant, (2) the recirculation of the heated water from the discharge(s) to the intake(s) of a power plant, (3) the reentrainment of the heated water from the discharge(s) of a power plant at the discharge(s) another power plant, and (4) the recirculation of the heated water from the discharge(s) of a power plant to the intake(s) of another power plant. The importance of all these effects which depend on the tidal flow conditions in the estuary, and the consequences of their exclusion in the near-field analysis of the discharges are clearly discussed on p. 3 - 18, Sec. 3.3.1, in Appendix E. It is further indicated that the realistic analysis of the thermal impact of power plant operations requires a far-field analysis which can include the critically important reentrainment and recirculation effects of the heated water from the multiple power plants on the Hudson River. Hence, the analysis of the thermal impact in the DEIS does not utilize directly the results of the near-field analysis based on the dilution ratios 2 - 6 which cannot incorporate the important effects of reentrainment and recirculation of the heated water.

Comment 19-33

Although a detailed evaluation of the thermal models used in the DEIS has not been conducted, the DEIS fails to address itself to the sensitivity of the models, the accuracy and limits of confidence associated with the results and the degree of prototype representativeness.

An overall review of the model and field study results presented in Appendix E indicates that the model (TMPTWO) overestimates the thermal impact in the vicinity of Bowline (2° to 3°F higher) and that in general, the agreement between the field observations and model results is very poor, considering that 1° to 2°F can make a large difference in whether there is a violation of criteria.

Response

1. The far-field mathematical model and its associated ESTONE computer code were applied to predict simultaneously (a) hydrodynamic, (b) thermal, and (c) salinity conditions in the Hudson River for two 6 - month periods 1 April - 30 September 1973 and 1974, without changing any coefficient and/or parameter in the model. Sensitivity studies are needed only if coefficients and/or parameters of a model need to be calibrated. The tidal-transient, one-dimensional discrete-element far-field model is a completely predictive model which does not require any major sensitivity study.

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   "The accuracy and limits of confidence associated with the results and the degree of prototype representativeness" is self-evident based on the comparisons of its results with the field-measured data for the two 6 - month periods 1 April - 30 September 1973 and 1974.

2. The general confrontation between the results of the mathematical models, including TMPTWO, and the field-measured data for the water temperature conditions in the Hudson River, including the vicinity of Bowline Point, is largely due to (1) the inaccuracies involved in the field measurements, and (2) the unrealiability of the data reduction methods used for obtaining the final temporal and spatial resolutions of the water information as presented in public documents. Detailed discussions of the field-measured data are included in Sect. 2.3 of the Appendix E of the FEIS.

Comment 19-34

The far-field model (ESTONE) used in the DEIS has not been adequately calibrated or verified.

Response

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"The far-field model (ESTONE) used in the DEIS" does not require calibration. It definitely has been validated for the Hudson River, (see Sect. 2.3, Appendix E of FEIS).

where.

Comment 19-35

No reference is made here to the source of meteorological data and the effects of various meteorological parameters on the model results, i.e., if in-land meteorological data were used, what would be the effects on river temperature? Some sensitivity analyses of the meteorological parameters ought to be presented.

Response

The detailed discussions of the input data to the ESTONE computer code for the meteorological conditions are presented in Sec. 2.4 in the FEIS.

Comment 19-36

In all prediction cases (3, 4, 5, 6, 7 and 8) considered here, "proposed maximum thermal load" was used. These represent unrealistic worst case conditions. The plants did not, and will not, operate at 100 percent capacity for 100 percent of the time. It would be far better and more realistic to use the operating rates as given, for example, on Orange and Rockland, 1977a, Section 2.1.3.6.

Case 3 is a very unlikely condition. Since the river takes several days to equilibrate, it is more appropriate to multiply maximum load by some plant factor.

Cases 3, 4, 5 and 8 should be excised from the DEIS as irrelevant to this study.

Response

Power-plant-operation conditions were modified in the supplementary study for Appendix E of the FEIS.

Comment 19-37

The accuracy of the predicted temperature, two decimal places, is questionable, particularly in view of the predicted level of noncompliance with the numerical criteria of 1°F (0.4 and 0.3°F for Bowline and Roseton/Danskammer, respectively).

If the ORNL intends to use such accuracy and predict such fine point violations, the model must be bounded by confidence limits based on sensitivity to input data and comparison to field data.

Response

The results of the predictions were presented accurate to two decimal places based on the printed computer output. The discussions of the thermal impact, according to the considerations of the State Thermal Standards were not based on two decimal place accuracy. In the discussions of the text, although the water temperature predictions were indicated with two decimal place accuracy, the violations of the State thermal standards were discussed only based on approximately half a degree accuracy.

Comment 19-38

It should be noted that exceeding the 83°F criterion over 50 percent of the cross-sectional area of the river (Cases 3 and 4) assumed plants operating at 100 percent capacity.

Response

Comment noted.

Comment 19-39

Experience to date indicates that the plume is a surface phenomena and thus it is unlikely that cross-section criteria will ever be exceeded.

Response

The statement indicates a lack of understanding of the important hydrothermal phenomena which control the far-field thermal impact of multiple-power-plant-operation on a tidal-dominated estuary (see Sect. 23., Appendix E of the FEIS).

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Comment 19-40

As indicated in a letter to the Corps of Engineers of October 13, 1977, the near-field and and zone matching portions of the ESTONE model and associated documentation have not been made available to the utilities' consultants. Accordingly, it was not possible to examine, in any detail, the inputs to, operation of, and predictions made by these models.

Response

"The near-field zone-matching portions of the ESTONE model and its associated documentation" does not exist. ESTONE computer code which is the associated computer code of the tidal-transient, one-dimensional, discrete-element far-field mathematical transport model was forwarded to the utilities. The remaining documents are being prepared as ORNL reports.

Documents never provid
to allow
usage.

Comment 19-41

It appears a dilution ratio of 2 was used in arriving at the occurrence of surface temperatures in excess of 91°F. Although such a low dilution was reported, its occurrence may be very rare. Also, it is not clear whether the model includes thermal stratification.

The EPA recommendations are irrelevant to these considerations and reference to them is misleading and should be deleted.

Detailed triaxial thermal measurements in the vicinity of Bowline do not support the statement that certain state criteria would be exceeded occasionally.

Field observations do not support the ORNL conclusion of the occurrence of surface temperatures and up-river effects have to produce surface temperatures in excess of 83.5 F at Bowline and simultaneously have the minimum recorded dilution of 2 in order to approach surface temperatures in excess of 91 F at Bowline. Existing ambient temperature measurements and the ORNL's own far-field calculations do not support the occurrence of such high temperatures (83.5 F) at Bowline, particularly considering that the dilution must simultaneously be low.

Response

1. The statement "It appears a dilution ratio of 2 was used in arriving at the occurrence of surface temperatures in excess of 91°F" is not correct. The tidal-transient, two-dimensional model does not use simplistic formulations based on any form of dilution ratio which automatically excludes the critically important reentrainment and recirculation effects in the estuary. The two-dimensional model uses complete flow fields based on the near-field and far field zone-matched hydrodynamic conditions, which include (a) the far-field freshwater flow and tidal flow conditions, and (b) the near-field intake and discharge flow conditions. Hence, the effects of reentrainment and recirculation are automatically included.

The model approximately includes thermal stratification.

2. The EPA recommendations were deleted.

3. "Detailed triaxial thermal measurements in the vicinity of Bowline" were not available for the analysis.

4. Appendix E of the DEIS did not state any "ORNL conclusion of the occurrence of surface temperatures and up-river effects at Bowline and simultaneously have the minimum recorded dilution of 2 in order to approach surface temperatures in excess of 91°F at Bowline." The comment indicates a lack of understanding of the reentrainment and recirculation phenomena that control the thermal impact in a tidal-dominated estuary.

Comment 19-42

The conclusion that the surface width and cross-sectional area 83°F criteria would be exceeded at Bowline appears to be based upon the results of the ORNL TMPTWO model. As indicated above, the model does not produce realistic results even if one assumes that the input parameters used are reasonable. Existing field data show that the affected surface width and cross-sectional area are bounded by a temperature rise of 4°F or by 83°F at Bowline. These temperatures are substantially below the N. Y. State thermal discharge criteria. Even if the full-load temperature conditions assumed in the model were to occur, the frequency and duration of violations would be insignificant.

Response

TMPTWO model does produce realistic results. The statement of the comment is not founded. "Existing field data show that the effected surface width and cross-sectional area are bounded by a temperature rise of 4°F and 83°F at Bowline" was not available for the analysis. This data, even if it does exist, cannot be compared with model predictions unless there exists the necessary compatibility between the data and the hour of measurements and the model predictions.

Comment 19-43

There are no data to support the third conclusion. In addition, the statement that excesses in temperature increase with decreasing freshwater flow is not true. In fact, just the opposite is true.

When freshwater flows are low, more cooler ocean waters will come into the estuary and may thereby decrease rather than increase temperatures. ONRL apparently hypothesized that temperatures will increase as a result of lower dilution due to decreased freshwater flow.

Response

The statement of the comment "In addition, the statement that excesses in temperature increase with decreasing freshwater flow is not true. In fact, just the opposite is true," indicates a lack of understanding of the hydrothermal phenomena that control the far-field thermal impact of multiple-power plant-operation on the Hudson River. The statement of the comment "when freshwater flows are low, more cooler ocean waters will come into the estuary and may thereby decrease rather than increase temperatures" can only be true for natural conditions without any power plant operating on the estuary. The comment indicates a general misunderstanding of the controlling hydrodynamic phenomena in the estuary. Freshwater flow is associated with the tidal-averaged convective transport which is the primary thermal transport phenomenon that controls the excess temperature conditions caused by the thermal discharges. "More cooler waters will come into the estuary" by the general mixing transport, which includes turbulent diffusion and dispersion, which is the secondary thermal transport phenomenon that affects the excess temperature conditions caused by the thermal discharges. Hence, the comment is false.

Furthermore, based on the definition of the ambient water temperature conditions, according to the State thermal standards, as "before the addition of heat of artificial origin," cooling of the water temperature conditions in the estuary by the cooler ocean water entering the estuary, from the ocean end, with multiple-power-plant-operation conditions, is identically the same cooling effect, without the operation of the power plants as represented by the "clean river" conditions. Hence, the relative excess temperature conditions caused by multiple-power-plant operation on the Hudson River cannot be reduced by the cooler water entering the estuary under lower freshwater flow conditions. Hence the comment is also meaningless from excess water temperature considerations.

Comment 19-44

General Comments on ORNL Thermal Model

The findings presented in the DEIS pages 4-6 through 4-9 indicating the 83°F regulatory criterion would be exceeded under certain conditions (maximum cross sectional area average temperatures of 83.80, 83.87 and 83.42°F are predicted at Indian Point) are questionable due to the following flaws in the ORNL thermal analyses:

The model verification is inadequate.

The comparisons of the model predictions with the field data presented on pages 3-115 through 3.-117 of Appendix E are generally inadequate with maximum differences ranging up to approximately 3.5°F. Differences for the 1974 verification period are given below:

Month	Days Showing Considerable Discrepancy	Discrepancy (Average Band-Field Data Range (F)
April	9-23	2.5 - 3.5
May	1-30	1.5 - 3.0
June	1-18, 27-30	2.0 - 3.5
July	1-5, 14-20	1.5 - 2.5
August	1-14	3.0 - 3.2
August	14-19	2.0 - 3.0
September	10-20	2.5 - 3.0

Discrepancies of these magnitudes between model predictions and field data are unacceptable for an analysis which purports to predict excesses of less than 1°F. Model predictions based on the ORNL verification are meaningless, particularly for critical periods when ambient temperatures are within 3 or 4 degrees of the regulatory criterion. For example, major discrepancies are noted for the critical period July 21 through August 14. The fact that the model overestimates the field data by more than 3°F indicate that the actual cross-sectional area average temperatures for the cases presented are probably nearer 80°F than 83°F.

An additional source of error in the verification may be in the conversion of the field data to cross-sectional averages. The field data were collected near the Indian Point intake and discharge and at other selected points. Comparison with model predicted "cross-sectional average temperatures" required that ORNL convert the field data. While considerable field data exist, it does not seem possible for ORNL to develop daily cross-sectional average field data for the entire period April through September 1974, without using some as yet unknown empirical conversion factor, which itself may be open to question.

The model scenarios for which the 83°F criterion is predicted to be exceeded are unrealistic.

Operation of all plants at maximum capacity over the same period of time, including the period needed for the river to equilibrate to such a steady-state condition, would be a rare occurrence when plant shutdowns, outages, maintenance and repair schedules and load cycling are considered. The model should be run with these factors incorporated for a realistic projection of the temperature regime in the river.

Inapplicability of EPA "Recommendation."

The DEIS and Appendix E refer to New York State water quality standards for thermal discharges as set forth in Part 704 of the New York Codes, Rules and Regulations. The New York thermal standards, as approved by EPA, however, do not include the EPA "recommendation" made in 1971 and 1973 (see references in DEIS, Appendix E, at p. 3-4) which had suggested that the mixing zone be limited arbitrarily to a 1,000 foot distance from the discharge.

Response

1. The statement of the comment "the model verification is inadequate" is not correct. The confrontation between the model predictions and the field-measured data is the result of the unreliability of the data (see Sect. 2.3 in Appendix E of the FEIS). The confrontation between two independent field-measured data sets is more pronounced than the confrontation between the model predictions and any single field-measured data set (see Sect. 2.3 in Appendix E of the FEIS).

2. The statement of the comment "An additional source of error in the verification may be in the conversion of field-data to cross-sectioned averages" is not correct. The field-measured data about the water temperature were not converted. Since the reduction of the field-measured data is always a part of the overall data acquisition program, no data reduction was attempted. The statement of the comment "while considerable data exists" is questionable, based on the considerations of the quality of the available data (see Sect. 2.3 in Appendix E of the FEIS). Furthermore, as stated above the responsibility of the reduction of the field-measured data, by "yet unknown empirical conversion factor" into a useful form always belongs to the group that had acquired the data.

3. Other power-plant-operation conditions for different fresh-water flow conditions in the Hudson River were considered in the Appendix E of the FEIS.

4. EPA "Recommendations" were deleted in the Appendix E of the FEIS.

Comment 19-45

Additional explanation is needed for the statement in Paragraph 4.25 concerning brackish or saline water "Evaporation."

Response

Paragraph 4.25 of the DES has been amended to clarify the statement regarding the evaporation of brackish or saline water.

Comment 19-46

The statement in Paragraph 4.27 that the operation of generating stations on the Hudson River estuary as a potential cause of degradation of the quality of the receiving waters has not been demonstrated by any evidence, and is in direct conflict with other statements in the DES.

Response

Paragraph 4.27 of the DES is an introductory statement acknowledging that heat and controlled amounts of contaminants are released in the liquid effluents from the Bowline Point Generating Station. As such, the effluents represent a potential cause of degradation in the quality of waters receiving the discharge from the power plant. Statements made in subsequent paragraphs indicate that monitoring has failed to reveal any measurable degradation in the waters of the Hudson River attributable directly or indirectly to the operation of the Bowline Point station.

Comment 19-47

Referencing the discussion of the liquid effluents from the closed-cycle cooling system discussed in Paragraph 4.41 of the DES, it is noted that chlorination for cooling towers may be continuous. It can be a problem under certain circumstances such as low chlorine demand or high hydrocarbon presence.

Response

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As mentioned in paragraph 6.20 of the DES, a closed cycle cooling system at the Bowline Point Generating Station would include dechlorination equipment to heat the blowdown, or liquid effluent, from the system. It may be anticipated that with such equipment in place and a chlorination schedule conforming to sound operating practices, the effluent from the system would meet applicable regulatory standards related to the discharge of chlorine.

Concern is being focused increasingly on the presence of hydrocarbons in the nation's surface waters and the possibility of producing toxic chlorinated compounds though the addition of chlorine in treating surface water for industrial and municipal uses. In accordance with the provisions of the Clean Water Act of 1977 (PL95-217), the U.S. Environmental Protection Agency is required to establish effluent standards reflecting the application of "best available technology" to control the release of a number of toxic substances including certain chlorinated hydrocarbons, from 21 categories of sources among which is the category of steam-electric power plants. Further, the U.S. Environmental Protection Agency has proposed regulations intended to control the release of toxic substances through the National Pollutant Discharge Elimination System program and to establish monitoring requirements related to these substances (43 FR 37078 et seq.)

The presence of certain toxic substances has been confirmed in waste streams of some coal fired power plants (U.S. Environmental Protection Agency, 1978). There is, however, little quantitative information on the source, transport and ultimate fate of these substances in the environment. Accordingly, it is impossible to estimate the potential risk associated with the release of chlorinated hydrocarbons, heavy metals or possibly other toxic substances from a closed cycle cooling systems at the Bowline Point Generating Station. It is expected that the effluents from such a system, if one is ultimately installed, would meet all applicable regulatory standards and conditons imposed through the National Pollutant Discharge Elimination System permit.

Comment 19-48

Referencing Paragraph 4.48 of the DES, it is noted that detailed field dissolved oxygen measurements in the thermal plume have been performed. No demonstrable reduction in dissolved oxygen was noted.

Response

There is no apparent disagreement between the statements made in this comment and that made in paragraph 4.48 of the DES. The latter, however, has been reworded in the interest of clarity.

Comment 19-49

Referencing paragraph 4.49 of the DES, it was noted that since August 1, 1976 the sulfur content in fuel oil burned at Danskammer has been 1.0% by weight. Since the switch from 2.0% sulfur oil at the plant, compliance with the federal 24-hour standard for sulfur dioxide has been achieved.

Response

A statement to this effect has been added to paragraphs 4.49, 4.51 and 4.70 of the DES.

Comment 19-50

The discussion in Paragraph 4.56 of the DES concerning a measurement program to observe the behavior of the plumes from the Bowline Point Station stacks is misleading.

Response

Paragraph 4.56 of the DES has been amended and now states that evidence indicates that the possibility of direct contact of the High Tor ridge by the plume is considered remote.

Comment 19-51

The ambient air quality standard for nitrogen dioxide is an average of the 24 hour concentrations over a consecutive twelve month period. The averaged monthly concentration (Table 4-6) should not be directly compared to this ambient standard as shown in the DES. In reality, the annual average value for the same period of time is 0.030 ppm, not 0.049 ppm.

Response

Comment noted.

Comment 19-52

Results of Orange and Rockland's analysis for environmental effects of cooling towers are presented in Orange and Rockland, 1977b; Section 5.2.

Response

Comment noted.

Comment 19-53

Referencing Paragraph 4.70, it is noted that since the switch from 2.0% sulfur oil at the Danskammer Plant, compliance with the federal 24-hour sulfur oxide standard has been achieved at Wheeler Hill Road Station.

__Response__

A statement to this effect has been added to paragraph 4.70 of the DES.

__Comment 19-54__

The analysis of potential salt drift from cooling towers at Roseton in paragraphs 4.71 and 4.72 of the DES assumed cooling tower specifications which are 20 percent higher than Roseton tower specifications, therefore resulting in smaller salt concentrations and fewer incidents of fog formation at ground level than would be expected with the towers determined to be appropriate by Central Hudson if cooling towers are required for Roseton.

__Response__

The analysis in the FES beginning at paragraph 4.102 includes the correct cooling tower parameters.

__Comment 19-55__

The analysis of potential salt drift from cooling towers at Roseton in paragraphs 4.71 and 4.72 of the DES assumed average year salinity levels in the Hudson River makeup water which are not indicative of salinity during drought years.

__Response__

Salinities during drought years has been considered in the revised analysis in the FES, beginning at paragraph 4.102 .

__Comment 19-56__

Contrary to the statement in Paragraph 4.75 of the DES, LMS has never developed models on adult striped bass entrainment.

__Response__

The text of Paragraph 4.79 of the FES has been revised to reflect this comment.

Comment 19-57

Contrary to the statement in Paragraph 4.76 of the DES, the Power Authority of the State of New York has never pursued a tag-recapture program for white perch or striped bass.

Response

The text of Paragraph 4.80 of the FES has been revised to reflect this comment.

Comment 19-58

The Corps comment on the "lack of adequate synthesis" of ecological data is not well founded. The January, 1977 (McFadden, 1977) report as well as the testimony and exhibits (Central Hudson 1977a, 1977b; Central Hudson, et al, 1977; Con Edison and Power Authority 1977a, 1977b; Ecological Analysts, 1977a, 1977b; McFadden, 1977; McFadden and Lawler, 1977; Orange and Rockland, 1977a 1977b; Stone and Webster, 1975, 1976; TI, 1977) submitted to EPA in July, 1977 contain such syntheses of the material the utilities believe to be of importance to the evaluation of effects on the fishery.

ORNL, a consultant to the Corps for this DES and its appendices, proposed the scope of work to be done (see Comments on Appendix B, below). ORNL was proposed as a consultant by the plaintiff Hudson River Fishermen's Association. ORNL also acts as consultant to EPA in the related EPA cases (see individual utility comments on the DES).

Response

These data have been incorporated into the FES.

Comment 19-59

The "First Annual Report for the Multiplant Impact Study of the Hudson River Estuary," was provided to the COE by letter dated September 4, 1975.

Response

These data have been incorporated into the FES.

Comment 19-60

It is inappropriate to divide yearly average deposition rates by 12 to determine potential for injury on a monthly basis. Substantial deposition can occur in a few hours if the meteorology is right. The degree of salt depositon will vary between months (for example, see Orange and Rockland, 1977b, Section 5).

The DES analysis calculated average annual salt deposition concentrations which mean very little when estimating damage done to foliage.

The use of short-term salinity concentrations prevalent during the summer months of drought years would yield higher deposition rates and would indicate the potential for damage to foliage during such periods. Such an analysis is included in Central Hudson 1977b. Similarly, with respect to Appendix E, Table 4.1.5 and Paragraph 4.3.4.2, the monthly River salinity values shown are typical of non-drought years and, during drought years, much higher salinity values could occur.

Response

The analysis of salt drift from cooling towers has been redone for the FEIS on a monthly average basis (see Appendix E of the FEIS and the FEIS beginning at paragraph 4.102).

Comment 19-61

Pertaining to DES paragraph 4.92, the amount of wetland to be eliminated at Greene County is detailed in both the Environmental Report (Power Authority, 1975a) and the application filed pursuant to Article VIII of the Public Service Law. (Power Authority, 1975b).

Response

Plans for the construction of the Greene County Power Plant have been cancelled by the Power Authority of the State of New York as of April 1979. Therefore, this reference to wetlands loss at the Greene County site has been deleted from the FES.

Comment 19-62

Pertaining to Paragraphs 4.94 through 4.119 in the DES, a more detailed and comprehensive discussion of expected impacts of Bowline may be found in Orange and Rockland (1977a), McFadden and Lawler (1977), Ecological Analysts (1977b).

Response

In the FES (Paragraphs 4.116), the discussion of Bowline Power Plant impacts has been revised to include new information from these references.

Comment 19-63

The differences in survival results for *Neomysis* at Bowline Point and Indian Point referenced in DES Paragraph 4.102 cannot be assumed to represent a disagreement without accounting for the possibility of differential net mortality and the comparability of temperature exposures during entrainment of this organism at the two plants. A more detailed discussion of *Neomysis* survival may be found in Orange and Rockland (1977a; Sections 8.2 and 8.3).

Response

The discussion of zooplankton impacts has been revised in the FES and reference to differential *Neomysis* mortality between Bowline Point and Indian Point has been deleted.

Comment 19-63a

Pertaining to comments made in DES Paragraphs 4.106 and 4.107, evaluation of ichthyoplankton entrainment abundance at the Bowline Point Generating Station may be found in Orange and Rockland (1977a; Section 9.2).

Response

The FES discussion of Bowline Point entrainment of fish eggs, larvae, and juveniles has been revised to include the information found in Orange and Rockland (1977a).

Comment 19-64

Pertaining to the statement made in DES Paragraph 4.108, only striped bass and white perch were analyzed in 1973 at Bowline Point; thus the unidentified larvae could have been *Alosa* spp., Atlantic tomcod or bay anchovy.

Response

The discussion of Bowline Point entrainment has been revised for the FEIS and the statement made in the DES paragraph 4.108 has been deleted.

Comment 19-65

With reference to DES Paragraph 4.111, the last sentence of this section invalidates the previous sentence, i.e. there was no problem. Also, a more detailed and comprehensive evaluation of entrainment survival information may be found in Orange and Rockland (1977a).

Response

This problem has been resolved by revising the discussion of entrainment at Bowline Point. The revised discussion presented in FES paragraph 4.128 includes new information from Orange and Rockland (1977a).

Comment 19-66

Pertaining to DES paragraphs 4.112 and 4.113, the definition of "normal" temperature exposure and ichthyoplankton survival is addressed in Orange and Rockland (1977a, Section 9.4). Atlantic tomcod survival for 1976 and 1977 may be found in Orange and Rockland, 1977a, Section 9.4.

Response

These sections have been rewritten for the FES (paragraph 4.129) and the statements in question have been deleted.

Comment 19-67

There is no inherent reason why the 27% ORNL mortality estimate for striped bass at Roseton supports the 24% ORNL estimate at Bowline. No rationale is presented for making the assumption in the last sentence of this section. Although limited data were involved, in contrast to the 1975 Roseton data referred to here, survival of yolk-sac striped bass at Lovett in 1976 was estimated at 100%. (EA, 1977a; Section 1.3.2).

Response

This section has been rewritten for the FES (paragraphs 4.128) and the statement in question has been deleted.

Comment 19-68

Reference to the sampling method used to estimate striped bass entrainment mortality at Indian Point is inadequate (DES Paragraph 4.115). Enough is known about net mortality problems in the survival studies at Indian Point to elaborate here. The probable bias introduced by the sampling method at Indian Point should be discussed. (See EA, 1977a; Sections 1.3 and 1.3.2).

Response

This section has been rewritten for the FES (paragraphs 4.128) and the statement in question has been deleted.

Comment 19-69

The last sentence of DES paragraph 4.116 should read, "Young fish in their first year of life generally dominated impingement collections".

Response

This section has been rewritten for the FES (paragraphs 4.134) and the statement in question has been deleted.

Comment 19-70

As presented in DES paragraph 4.118, unadjusted impingement rates, without scale-up, provide lower estimates of impingement at Bowline Point (Orange and Rockland, 1977a, Section 10.2). Employment of a collection efficiency of 0.5 by ORNL is not supported by existing data. (Orange and Rockland, 1977a, Section 10.2.3.1.3, p. 10.2-10).

Response

This section has been rewritten for the FES (paragraphs 4.131), and the statement in question has been deleted.

Comment 19-71

Impingement survival at Bowline Point as mentioned in DES paragraph 4.119, may be found in Orange and Rockland, 1977a, Section 10.3.

Response

The sections have been rewritten in the FES (paragraphs 4.131), and the statement in question has been deleted.

Comment 19-71a

Pertaining to paragraph 4.126 of the DES, chlorination has been discontinued at the Roseton and Danskammer plants in favor of mechanical condenser cleaning.

Response

The section has been rewritten in the FES (paragraph 4. 143) and the statement in question has been deleted.

Comment 19-72

Contrary to the statement made in DES paragraph 4.134, data regarding numbers of ichthyoplankton of key fish species entrained at the Roseton station through the year 1976 are given in the evidentiary material filed with EPA Region II on July 11, 1977 (Central Hudson, 1977a).

Response

This section has been rewritten for the FES (paragraphs 4.149) to include the recently available data on 1976 entrainment at Roseton.

Comment 19-73

The findings of Ecological Analysts (1977a, 1977b) should be added to the discussion of cumulation impacts on phytoplankton, zooplankton, and benthos found in DES paragraphs 4.140 to 4.152.

Response

The results of this recent study have been included in the FES when appropriate. See paragraphs 4. 162 to 4.172.

Comment 19-74

Contrary to the statement made in DES paragraph 4.158, insufficient data exist to allow the statement that Atlantic tomcod yolk-sac larvae are distributed throughout the water column. (McFadden, 1977 at Section 14.42, p. 14.14).

Response

The discussion of multiplant entrainment effects has been rewritten for the FES (paragraphs 4.173), and the statement in question has been deleted.

Comment 19-75

The estimate of entraiment for Unit 1 of Indian Point in Table 4-19 of the DES is based on Unit 2 concentrations rather than on river concentrations as stated in the footnote. In addition, "August 1974" in footnote d of Table 4-19 should be changed to September 1974.

Response

This table has been deleted from the FES.

Comment 19-76

Contrary to statements made in DES paragraph 4.162, fish impingement data (all species) are reported monthly as well as annually in utility reports. (See generally the "Indian Point Impingement Study" reports for 1972-73, 1974 and 1975 which were provided to the Corps of Engineers by letters dated February 20, 1975, December 11, 1975 and December 20, 1976, respectively). Furthermore, reports prepared for Orange and Rockland (LMS, 1974; LMS, 1975; LMS, 1976 and Orange and Rockland, 1977a; Section 10.2) report on impingement data of striped bass, white perch, Atlantic tomcod, and other species.

Response

This section of the report has been rewritten in the FES (paragraphs4.180). Where appropriate the revised version provides more detailed information on Hudson River power plant impingement of fish.

Comment 19-77

Power plant impacts on blueback herring and shortnose sturgeon were not calculated but were discussed in McFadden (1977 at p. 14.19). Accordingly, despite the implication in the DES at paragraph 4.162, the equilibrium reduction equation was not applied for impact assessment on these two species.

Response

This section has been deleted from the FES.

Comment 19-78

The impingement data presented in Table 4-22 of the DES should not be expressed as number per million gallons, but rather as number per million cubic meters. In addition, although not significantly different, the data presented in this table should be updated in light of the data presented in Supplement 1 to the January, 1977 report (McFadden and Lawler, 1977). The derivation of the impingement rates at Cornwall is unclear, since the plant does not exist. Further, it is improper to consider the Cornwall project here as it has no bearing on the subject proceedings, nor can it be used as a determinant for the installation of cooling towers in 1982 when it will not become operational until 1988-89.

Response

Table 4-22 (DEIS) has been deleted from the FES.

Comment 19-79

It is unclear why, in Table 4-23 of the DES, different factors were applied to the impingement estimates at Bowline, Indian Point, and Roseton when the cooling system is changed from once-through (OT) to closed-cycle (CC). For instance, the impingement estimate at Bowline with CC cooling is 2% of that with OT cooling, whereas at Indian Point it is about 9% and about 4% at Roseton. The higher factors applied to the Roseton and Indian Point impingement estimates require justification.

Response

Table 4-23 (DES) has been deleted from the FES.

Comment 19-80

Instead of the use of closed-cycle cooling, modification of all intakes with the installation of screens or deflection devices could also reduce impingement, and would cost less than cooling towers. (See, for example, Stone and Webster, 1975, 1976a and 1976b; and Exhibits 16 and 22 of the July 11 filing with EPA, all of which have been supplied to the Corps of Engineers).

Response

Studies on the use of nets in front of the intake structures at Bowline Point are summarized in the Bowline Point impingement section of the FES (paragraph 4.138). In addition, the concept of using screens or deflecting devices to reduce impingement impacts is discussed in Paragraphs 6.58 through 6.60, Modification of the Present Permit--Improvements to Plant Intake.

Comment 19-81

Unlike Indian Point Unit 2 where impingement collection efficiency may be less than 100% due to the air bubbler and once-a-day washing of the vertical fixed screens, the collection efficiency at Bowline and Roseton should be very high. (See Orange and Rockland, 1977a, Section 10.2). Application of a collection efficiency of 0.5 to Bowline and Roseton impingement estimates, as discussed in DES paragraph 4.170, surely results in a gross overestimation of impingement impacts at these plants.

Response

This section has been deleted from the FES.

Comment 19-82

In paragraph 4.172 of the DES it is stated that the extent to which the Ricker theory is applicable to estimating the ultimate effects of power plant generation on Hudson River fish populations is presently unresolved. Supplement 1 (McFadden and Lawler, 1977) to the January 1977 Report (McFadden, 1977) presents a detailed analysis and application of Ricker's stock-recruitment theory in estimating the ultimate effects of power plant operation on Hudson River fish populations.

Response

Information in Supplement 1 (McFadden and Lawler, 1977) have been used in preparation of the FES. A discussion of the applicability of the Ricker theory is included in material beginning at paragraph 4.187 .

Comment 19-83

Values of percentage losses from entrainment and impingement given in Table 4-24 of the DES have been updated in McFadden and Lawler (1977) at p. 2-VIII - 36, 37.

Response

These data have been used in the FES.

Comment 19-84

The issue discussed in paragraphs 4.180 and 4.181 of the DES is not the existence of striped bass compensation but its extent and operation. The existence of compensation has been shown empirically for striped bass populations. The commercial fishery catch data provide precisely the long time-series which the DES requires to "determine empirically the existence of compensatory relationships within a fish population."

Response

The most recent Utility analyses to demonstrate empirically the existence of compensation in striped bass and white perch populations of the Hudson River are evaluated beginning at paragraph 4.192 of the FES.

Comment 19-85

Estimates of entrainment mortality (f_c) presented in Table 4-25 of the DES are obsolete in light of the updated 1975 and 1976 entrainment survival data available since the DES was issued.

Response

A discussion of entrainment mortality utilizing more recent data can be found beginning at paragraph 4.173 of the FES.

Comment 19-86

The large ranges of f_I factors presented in Table 4-27 of the DES are due not to the quality of the data, but to the wide variations in the distribution of striped bass ichthyoplankton from year to year and from one plant site to another. More recent data can be found in McFadden and Lawler (1977).

Response

More recent data have been incorporated into the FES at paragraph 4.173 .

Comment 19-87

Instead of the values for entrainment mortality given in Table 4-26 of the DES, the Corps should use the results from larval table sampling. The larval table results are much better mortality estimates.

Response

These recent data have been used in the FES.

Comment 19-88

The interpretation of the analyses pertaining to the best lag time to use in pairing spawners with the resulting recruits may be more complex than the presentation given in paragraph 4.187 of the DES.

Response

More recent analyses of the appropriateness of the Utilities choice of a 5-year lag time in matching data on spawners and recruits for striped bass in the Hudson River is presented beginning at paragraph 4.229 of the FES.

Comment 19-89

McFadden and Lawler (1977) presents a revision of the analysis of population density effects on growth of young striped bass as given in paragraph 4.188 of the DES. After corrections in the raw data, the negative relationship between density and growth reported in the DES is no longer apparent. However, this does not mean that such a relationship does not exist. The Corps should refer to studies of the Roanoke Albemarle system by the University of North Carolina at Raleigh (Hassler and Hogarth, 1970) and on the West Coast (Chadwick, 1964; 1968). (See white perch work by Mansueti, 1961 and by Hergenrader and Bliss, 1971, on growth and population density).

Response

The most recent Utility analyses to demonstrate empirically the existence of compensation in striped bass and white perch populations in the Hudson River are evaluated beginning at paragrah 4.187 of the FES.

Comment 19-90

Section 2-IV of McFadden and Lawler (1977) provides an extensive analysis indicating "the range of mortality rates resulting from power plant operations that could be offset by compensatory responses and the degree of offset".

Response

Data from McFadden and Lawler (1977) have been incorporated into the FES at paragraph 4.187 of the FES.

Comment 19-91

Utilities disagree with all four contentions of the staff of the Oak Ridge National Laboratory presented in paragraph 4.192 of the DES regarding the form of compensation function used in the Lawler, Matusky, and Skelly model of long-term fish population reduction.

Response

The model referred to is no longer used by the Utilities to estimate long-term impacts and has been deleted from the FES.

Comment 19-92

In reference to the values given in paragraph 4.194 of the DEIS for entrainment mortality used in the Oak Ridge National Laboratory model runs used to estimate long term impacts to striped bass, mortality for organisms entrained in a closed cycle cooling system is 100 percent.

Response

This model is no longer used by the Oak Ridge National Laboratory and has been dropped from the FES.

Comment 19-93

The large reduction in striped bass adult population size predicted by the Oak Ridge National Laboratory model as presented in Table 4-31 and discussed in paragraphs 4.196 and 4.197 of the DES is due principally to the modification of the compensation function as proposed by Lawler, Matusky, and Skelly. Utilities disagree with the modification of the function. Also, Utilities disagree with the inclusion of the effects of the Danskammer and Lovett plants since their impacts on fish populations is already reflected in the baseline conditions.

Response

This model is no longer used by Oak Ridge National Laboratories or the Utilities to predict long-term impacts and has been dropped from the FES.

Comment 19-94

The Utilities agree that the runs of the Oak Ridge National Laboratory population model that use no compensation, as discussed in paragraph 4.198 of the DES, are unrealistic.

Response

This model is no longer used by the Oak Ridge National Laboratory and has been dropped from the FES.

Comment 19-95

The "increase" in the magnitude of effect from annual loss of young-of-the-year compared to the reduction in adult stock after 40 years as predicted by the Oak Ridge National Laboratory population model and discussed in paragraph 4.199 of the DES is due to the form of the compensation function used. Utilities disagree with the form of the Laboratory's compensation function.

Response

This model is no longer used by the Oak Ridge National Laboratory or the Utilities and has been dropped from the FES.

Comment 19-96

Utilities disagree with Oak Ridge National Laboratory in restricting compensation to the entrainable life stages only in their population model of long term impact, which is discussed in paragraph 4.202 of the DES. The Laboratory has offered no evidence that compensation does not occur during the impingeable life stages.

Response

This model is no longer used by Oak Ridge National Laboratory to predict long-term impacts and has been dropped from the FES.

Comment 19-97

The equilibrium model (i.e. Equilibrium Reduction Equation [ERE]) discussed in paragraph 4.203 of the DES is not an extension of the Lawler, Matusky, and Skelly model used by Oak Ridge. The ERE was developed independently by Texas Instruments.

Response

This statment has been removed from the FES.

Comment 19-98

The long-term reduction in the adult population level of striped bass in the Hudson River as predicted using the Real-Time Life-Cycle Model has been revised upward to 8 percent (McFadden and Lawler, 1977) from the value of about 5 percent given in the DES in paragraph 4.204. Also the characterization of the Oak Ridge National Laboratory population model in the DES as employing "strong compensation" is completly unfounded. As indicated above, the largest amount of compensation in Table 4-31 (KXO/KX = 0.5) corresponds to an extremely low level of alpha (1.4). The percentage reductions in Table 4-32 at KXO/KX = 0.5 (13 to 15%) correspond to a more realistic, yet still conservative, level of alpha (3.2).

Response

An analysis of the Real-Time Life-Cycle Model is given in the FES beginning at paragraph 4.241 . The Oak Ridge National Laboratory no longer uses the population model to predict long-term impacts, and it has been dropped from the FES.

Comment 19-99

Much more important reasons for the differences in the impact predictions obtained by the Utilities and the Oak Ridge National Laboratory, than those given in the DES beginning at paragraph 4.205 are:

(1) The amount of compensation operative;

(2) Differences in entrainment survival estimates; and the 50% impingement collection efficiency erroneously applied to Bowline and Roseton data by ORNL.

Response

Oak Ridge National Laboratory no longer uses the population model discussed in the DES and has made no new predictions of long-term impacts to fish populations. Comparisons with present Utility estimates are not possible in the FES.

Comment 19-100

Ricker's methodologies for assessment of exploitation may be applied in a manner which allows natural mortality to be held to be negligible or in a manner in which exploitation occurs over a period of months during which a high rate of natural mortality occurs. Texas Instruments (TI) in applying Ricker's methodologies initially elected to apply them in a manner which discounted concurrent natural mortality. Subsequent to the issuance of McFadden (1977) in which this methodology was developed and presented (Section II), it was pointed out to TI that a more appropriate approach would be to account for natural mortality throughout the rather long period of exposure to power plants. This is the reason for the use of the term "misinterpretation". Utilities believe the use of the word "error" in paragraph 4.206 of the DES is incorrect.

Using the revised interpretation of Ricker's analysis and the recalibration of the LMS Model results in a prediction of multi-plant impact at 40 years of 8% (McFadden and Lawler, 1977, Section 3-VIII).

Response

The reference to an error in analyses has been removed from the FEIS. An analysis of more recent Utility estimates of long term reduction in fish populations begins at paragraph 4.205 of the FES.

Comment 19-101

It is stated in paragraph 4.207 in the DES that the population models used to predict impact to fish populations by the Utilities and Oak Ridge National Laboratory were different in that the Utility analysis used a level of compensation stronger than the strongest case considered by Oak Ridge.

The most important difference in the application of the models however, was Oak Ridge's disabling of the left limb of the compensation function.

Response

These models are no longer used to predict long-term impacts and have been removed from the FES.

Comment 19-102

It is stated in paragraph 4.208 of the DES that Oak Ridge National Laboratory noted a larger effect of impingement in their runs of the population model than did the Utilities in their runs of the same model. The important effect of impingement when strong compensation was assumed in the Oak Ridge runs was thought to account for the difference. As explained in Comment 19-98, "strong compensation" was not assumed in any of the Oak Ridge runs. Inflated impingement rates due to the unfounded application of a 50% collection efficiency at Bowline and Roseton probably caused the greater estimate of impingement impact.

Response

These models are no longer used to predict long-term impacts and have been removed from the FES.

Comment 19-103

It is stated in paragraph 4.210 of the DES that differences in values of entrainment mortality were probably not responsible for the larger differences in estimates of long-term impacts to the adult striped bass made by the Utilities and the Oak Ridge National Laboratory. The Utilities believe that differences in the values chosen for entrainment mortality do contribute to the differences in impact predictions. Oak Ridge used three different levels of intake factors. These are not all similar to the values used by the Utilities.

Response

These older models are no longer used to predict long-term impacts and have been dropped from the FES.

Comment 19-104

In paragraph 4.219, the notion of arriving at an equitable distribution of benefits and costs is mentioned. However, the Corps of Engineers has not provided any cost/benefit evaluation for the alternatives proposed. Furtheremore, no cost/benefit or comparative evaluation of alternatives to closed-cycle cooling has been provided in the DES.

Response

As indicated in paragraph 4.02 of the DES and the introductory portions of section 6 dealing with alternatives, the analysis presented in the DEIS focuses on the costs and benefits associated with alternaitve options available to the District. However, the analysis encompasses cooling alternatives (paragraphs 6.09 through 6.56 of the DES) and alternatives to closed cycle cooling (paragraphs 6.58 through 6.62 of the DEIS), although regulatory decisions on these matters are not within the purview of the District. This is consistent with the directives of the National Environmental Policy Act on the question of alternatives and allows the District to assess the implications of its own action under a range of conditions representing the possible outcome of actions taken by other agencies.

Comment 19-105

The visual impact of the Bowline Point Generating Plant will be exacerbated by the construction of the proposed cooling towers.

Response

A discussion of the visual impacts of the Bowline Point Station are given beginning at Paragraph 4.251 of the FES.

Comment 19-106

Referencing paragraph 4.224 of the DES, Orange and Rockland has optimized the cooling tower design to the lowest possible height, which is 393 feet. The base diameter would be 315 feet.

Response

A note has been added to Figure 4-14 of the DES to indicate that the artist's impression given in this figure is based on a preliminary design and that the height and base diameter of the towers have been reduced according to a later design. The appropriate changes have been made in paragraph 4.224 and 6.18 of the DES.

Comment 19-107

Utilities support the fact in paragraph 5.10 of the DEIS that there are alternatives to cooling towers, which could be implemented at far less cost, in lieu of cooling towers, if impacts were deemed unacceptable. These alternatives could include modified operation of the circulating water system to optimize entrainment survival, modification of the intake structure to reduce impingement, or stocking Hudson River striped bass. (See Orange and Rockland, 1977a; Section 9.4.4.3.3, p. 9.4-58; Stone and Webster, 1975, 1976a, 1976b and Texas Instruments, 1977.)

Utilities disagree that it is impossible to predict how successful alternative measures would be, based upon the research results reported above.

Response

Comment noted

Comment 19-108

Paragraph 5.14 of the DES notes that the presence of polychlorinated biphenyl compounds in the Hudson River is a factor that warrants consideration as elements of risk associated with the long-term operation of the power plants with closed-cycle cooling. The comment notes that the presence of these compounds has resulted in the prohibition of commercial fishing in the Hudson River and in the limitation of the number of fish taken by sports fishermen for consumption.

Response

Mention is made in paragraph 2.37 of the DES of the ban on commercial fishing in the Hudson River and the advisory on limiting the intake of fish from the Hudson River as a result of elevated levels of polychlorinated biphenyl compounds (PCB's) in the river. Available information, given in Figures 2-16 and 2-17 of the DES, indicates that annual commercial landings in the Hudson River Valley have been of the order of 300,000 pounds for American shad and less than 100,000 pounds per year for alewives and striped bass.

This ban represents a monetary loss to the commercial fishermen of the Hudson River Valley but, clearly is unrelated to the operation of the Bowline Point Generating Station and the other power plants on the river. In the long term, it appears reasonable to suppose that the present prohibition on the discharge of PCB's, possibly accompanied by efforts to decontaminate the river, will lead to reduced levels of these compounds in the river. Commercial fishing may resume and the potential effects of the power plants on the fishing industry then become a relevant consideration. It is difficult, however, to estimate the magnitude of these effects in terms of financial losses for a number of reasons. Principal among them is the uncertainty concerning the effects of the power plants on populations of fish in the Hudson River, as discussed in detail in various sections of the DES.

Beyond this uncertainty, several factors must be considered in relating possible reductions in standing stocks to financial losses to the regional fishing industry. Market conditions, such as the demand for a particular type of species of fish and the value of the product, rather than standing stops could be the principal determinants of the commercial catch. The seasonality of commercial landings may be another important factor in terms of the size and nature of the fishing industry that can be maintained. Nonetheless, a reduction in standings stocks can, in general, be related to a reduction in catch-per-effort and, in turn, to a loss in the earnings of commercial fishermen.

Comment 19-109

Orange and Rockland Utilities, Inc. and Central Hudson Gas and Electric do not agree that the Corps has any legal authority to place operating restrictions on the Bowling Point or Roseton generating stations.

Response

Current regulations authorize the District Engineer to re-evaluate the circumstances and conditions of a permit either on his own motion or as the result of periodic progress inspection, and to initiate action to modify, suspend or revoke a permit as may be made necessary by considerations of the general public interest. All factors which may be relevant must be considered in this review, including conditions of conservation, economics, aesthetics, general environment concerns, historic values, fish and wildlife values, safety, land use, water quality, and in general, the needs and welfare of the people.

Comment 19-110

It is believed that problems associated with backfitting a plant designed for once-through cooling, the aesthetic impact of massive towers and their plumes, and 100 percent mortality of entrained organisms will probably be ecologically disadvantageous along with salt drift.

Response

Comment noted.

Comment 19-111

Paragraph 6.48 of the DES discusses measures aimed at reducing the amount of cooling water that is withdrawn from the Bowline Pond and circulated through the power plant. Based upon organism thermal tolerance information, the utility believes that careful consideration must be given to the operating mode of the recirculating water system.

Response

Comment noted.

Comment 19-112

Paragraph 6.57 of the DES notes a number of other mechanisms in addition to thermal shock through which biota are injured or destroyed. However, larval table data at Bowline show that temperature is the main determinant of mortality.

Response

Comment noted.

Comment 19-113

The discussion of potential improvements to plant intake structures in paragraph 6.58 - 6.60 of the DES should be expanded.

Response

An expanded discussion of the possibility of installing alternative intake structures at the Bowline Point Generating Station now replaces the discussion given in paragraphs 6.58 through 6.60 of the DES.

Comment 19-114

Paragraphs 6.61 and 6.62 of the DES discuss the concept of a comprehensive management program within the New York Power Pool which would, inter alia, restrict certain power plant operations depending upon ecological conditions. This concept should be explored in greater detail and should particularly address the responsibility of the member utilities to supply adequate and reliable electric service at lowest possible cost to the consumers in New York State. The Corp's limited authority over implementing such a program should be addressed.

Response

No statement made in the DES is intended to be contradictory to the substance of this comment. As mentioned in paragraph 6.62 of the DES, the notion of "ecological dispatch" is a suggestion based on limited ecological information, with evident need for more data and analysis to formulate a comprehensive management program. Editorial and other changes have been made in Paragraph 6. 70 of the FES to emphasize that "ecological disptach" can be considered at present only as a possibility of undertermined ecological, technical and economic viability.

Comment 19-115

In the first sentence in paragraph 6.77 of the DES, change Bowline Point to Roseton. The last sentence should read: "The increased fuel consumption is estimated to be on the order of 2.5 million barrels of fuel oil per year with a spot market value in excess of $45 million per year."

Response

The obvious error in paragraph 6.77 of the DES has been corrected. A revised estimate shows that the additional fuel consumption associated with the suspension of the Roseton is 2.5 million barrels of fuel oil per year as indicated in this comment, and not 2.0 million barrels per year as indicated in the DES. In order to maintain consistency throughout the analysis, a value of $37.5 to $40 is assigned to this increase in consumption on the basis of 1976 spot prices of fuel.

Comment 19-116

It is misleading in paragraph 7.04 to lump all short-term uses of man'e environment along the estuary as if they all caused reductions in productivity.

Response

Editorial and clarifying changes have been made in paragraph 7.04 of the FES.

Comment 19-117

The implication in paragraph 8.09 of the DES that striped bass are selectively stressed is incorrect.

Response

The argument presented in paragraph 8.09 of the DES is an expansion of the possibilities identified in paragraph 8.07 as potential irreversible, or permanent impacts. With the present state of knowledge of the aquatic ecosystem of the Hudson River estuary, the argument is, of necessity, based mostly on theoretical considerations. Among these is the possibility that striped bass are selectively stressed with respect to other species because of different characteristics in life cycles of the fishes. For example, the particular spawning habits of striped bass could, in principle, render their progeny more or less susceptible to entrainment and impingement. The sensitivity of eggs and larvae to entrainment and survival among impinged juveniles in many cases is known to vary from species to species. It is conceivable, therefore, that one or more species could be selectively stressed and that the irreversible impacts identified in paragraph 8.07 of the DES could materialize.

Comment 19-118

Appendix B is incomplete in that it does not contain a copy of the September 22, 1976 Order of Judge Metzger in Hudson River Fishermen's Association, et al., v. Orange and Rockland Utiltiies, Inc., et al., (72 Cir. 5460).

Response

A copy of the Order has been included in Appendix B in the FEIS.

Comment 19-119

Appendix C suggests that the generation from Roseton and Bowline is not necessary, speculating that other generation sources are or will be available. These unwarranted conclusions are completely incorrect.

Response

Appendix C provides detailed information to support certain findings and conclusions made in the body of the report. A statement to this effect has been added to the introductory paragraph of the Appendix to ensure that it's intended purpose is clearly defined.

Responses to the more specific comments that follow will effectively address the broad points of contention contained in the above comment.

Comment 19-120

In devising the long-range plans of the New York Power Pool, the investor-owned member utilities are limited by a number of external constraints. These companies have severe financial constraints on the investment of new capital and are required by their managements and stockholders, and by regulatory authorities, to justify the commitment of funds to new facilities. While the projection of future load is an important factor in the decision to construct a plant, this factor does not stand alone. The environmental constraints on new facilities, the attitude of, and legal restraints imposed by, local governments, the local tax burden on a facility, the attitude and productivity of the labor environment, and the price resistance of customers all confine the planning for the construction of new facilities.

Response

A discussion on the significance of projections of peak load in planning additions to generating capability is given in the third paragraph on page C-11 of the DES. In the discussion it is pointed out that all projections represent the primary basis, and not the exclusive basis, for planning. The factors enumerated in the above comment compliment the information given in the DES and point to the advisability of allowing for contingencies in long-range generation plans. A discussion of the effects of such contingencies is given on pages C-18 through C-20 of the FES.

Comment 19-121

National policy requires the limitation, to the extent possible, of the need to burn oil. Accordingly, the long-range plans of the Power Pool now envision expansion of power generation using coal and uranium fuel.

Response

A description of the Power Pool's long range plans given in the first full paragraph on page C-18 of the DES indicates that nuclear fueled power plants constitute approximately 64 percent of the additional generating capacity scheduled to be installed between 1976 and 1991, with coal and oil fueled power plants constituting respectively 15 percent and 9 percent of additional capacity.

Comment 19-122

Changing environmental and regulatory requirements and procedures have limited the Pool's ability to estimate the total time needed for planning and construction of new generating units. Two major uncertainties -- a return to the higher trends of long-term load growth rates as the effects of the national recession ease, and a delay in bringing units on the line must be considered in planning. In developing the Pool plan, the most reasonable estimates permit allowance for the detrimental effects of either, but not both, of these two major uncertainties. The Pool's present forecasts reflect the lower growth rate of the past three years and the impact of conservation efforts. These lower growth rates run counter to both historical trends and to the fact that the trend of consumption of other forms of energy for other purposes has not experienced similar declines.

The current experience is that the overall time required to put generation into operation is actually increasing due to several factors, including regulatory delays, construction delays, enforced regulatory modifications, and litigation. Utilities believe that it is becoming increasingly more difficult for new generation to become productive in the anticipated time.

The Power Pool plan recognizes the two major uncertainties, provides for the occurrence of one or the other (but not both), and develops a plan which projects reserves of large magnitude, if all occurs according to assumptions; and it includes an optimistic perspective of the time required to implement the plan. However, the plan is not the fact; and if a fortuitous set of circumstances should combine to permit perfect implementation, action obviously would be taken in later plans to delay future, uncommitted plants. Each plant must receive a certificate for construction, on an individual basis, in a procedure in which the then current need for the plant is thoroughly examined.

Response

The summary of the New York Power Pool's long range generation plan given on pages C-18 through C-20 of the FES confirms the prediction that adequate reserve margins could not be maintained with both a load growth higher than anticipated and additions to capacity coming on line on a delayed schedule. As indicated in the above comment, the addition of new capacity can be delayed if either one of these contingencies, considered adverse from the standpoint of planning, fails to materialize fully.

Comment 19-123

The high future level of reserves indicated in the Pool plan will, in all probability, never be realized. The present relatively high level of reserve is the result of the economic downturn experienced nationally and its lingering effects which are still prevalent in the northeast sector of the country.

Many of the plants currently in place were authorized and built during the late 1960's and early 1970's, when growth rates demanded the construction of these facilities. In recognition of the need to reduce the cost of energy (presently among the highest in the country), it is necessary to run the least costly existing units to generate electricity to reduce the effect of energy costs on the heavily burdened people. The Roseton and Bowline plants, which are among the most efficient plants in the Pool, thus are an asset to this area.

The implication in the DES that other units can be run in place of Roseton and Bowline does not take into account the economic impact of energy costs on the consumer and, to the extent that this economic burden on the customer is disregarded, does not create the necessary background for the value judgments that need to be made in an environmental impact statement.

Response

The monetary as well as energy costs associated with the loss of generation from the Bowline Point and Roseton stations are discussed in paragraphs 6.73 and 6.75 of the FES. As indicated in these paragraphs, the generation of energy to replace the energy produced by the Bowline Point station would entail a penalty estimated on the basis of 1975 records to be of the order of 10,500 billion Btu, the equivalent of 1.75 million barrels of oil valued at $26 to $28 million at 1976 prices. The corresponding figures for the Roseton station, given as 2 million barrels of oil and $30 million per year in the DES, have been revised in the FES to 2.5 million barrels valued at $37.5 to $40 million at 1976 prices.

Comment 19-124

To imply that the simple solution of using gas turbines is a viable alternate to generation with modern steam-electric plants is completely erroneous and contrary to the public interest. Gas turbines are used for peaking purposes and are intended to run for short periods of time to supply short-time peak loads. They are less costly from a capital point of view, but inherently much more expensive because of the fuel used and because of their low efficiency.

The current technology of gas turbines requires that they be fueled with distillate products which are more expensive than the residual oil, coal, or uranium fuel used in large plants. The overall cost of electricity from these turbines, when operated for equivalent time periods, is substantially greater than that of large steam-electric plants. Furthermore, the impact of the heavy consumption of this fuel, for electric generating purposes, on the market price of the product, which may be used for home heating oil, diesel fuel or jet engine fuel, will force the price of these products to rise, or in some instances may produce shortages. This impact on the prices paid by the consumer for many products cannot be dismissed. The supply of this fuel and these products is not geared to large consumption by utilities.

In the case of pumped storage developments, which are also part of the generation expansion plan, the investor-owned utilities are assessing the viability of such developments, on an on-going basis. For some time to come, it will be economic to supply electricity from the present oil fueled plants to run these units. Of course, to the extent that these pumped storage plants exist, it will be best to utilize the most efficient units to pump them, thus increasing the need to run units such as Roseton and Bowline.

Response

There is no intent in the analysis presented in the DES to imply that gas turbines would be used to replace the power generated by the Bowline Point or Roseton stations in the event of operations being suspended at these stations. What is assumed in the analysis (paragraph 6.75 and 6.86 of the FES) is that replacement power would be supplied from all sources controlled by the New York Power Pool. It is assumed that the major portion of the replacement power would be derived from steam-electric facilities which make up the largest part of the generating capability available to the Pool. Since this is likely to involve an increased usage of older, less efficient equipment to meet base load, the energy and cost penalties discussed in response to a previous comment are given in the analysis.

It may be well to note that the economy and reliability of supply associated with the continued, unencumbered operation of the Bowline Point and Roseton generating stations are recognized as benefits in this analysis (Paragraphs 6.06 and 6.78 of the FES). The loss of these benefits is considered as one of the consequences of suspending operations at the two generating stations until closed cycle systems can be installed. This loss is next contrasted to the benefits to the aquatic ecosystem of the Hudson River Estuary expected to result from a temporary suspension of operations. In both the case of the Bowline Point and the Roseton Stations, such benefits to the aquatic ecosystem are taken to be negligible. Accordingly, further investigation into the question of whether a suspension of operations at the two stations would lead to interruptions in customer service is considered unnecessary.

In the context of an indefinite suspension of operations, or abandonment of the Bowline Point and Roseton generating stations, the economic penalties considered in connection with a temporary suspension of operations are inconsequential in comparison to the current worth of the plants and the cost of replacement capacity.

Comment 19-125

Utilities believe, therefore, that from a long-range planning point of view:

1) The availability of actual reserves will, in practice, closely approach the fundamental level required for reliability, and excess reserves will not be available for large purchases.

2) The social implication of increased energy costs to consumers cannot be ignored in the evaluation of alternate electricity supplies to consumers.

3) The relatively efficient and economical Roseton and Bowline plants are cost-justified and must be run for the benefit of the consumers and the improvement of the economic environment.

4) Gas turbines are not a viable alternative for required base-load generation nor is the development of pumped storage facilities.

Response

Detailed responses have been given previously on the need for the Bowline Point and Roseton Generating stations.

Comment 19-126

As to the Roseton Plant and Central Hudson Participation:

Load and capacity data used in the subject DES were largely drawn from the Long-Range Plan presented to the New York Public Service Commission in 1976. This plan is updated annually and each year a formal presentation is made. The 1977 Plan contains further modifications. In this iterative process, Central Hudson has made changes in its load and capacity program, but more importantly, in 1977 has modified its agreement to participate in the ownership of Roseton, responsive to the decline in its anticipated load. It is also important to be aware that as part of the Roseton Agreement, Central Hudson has agreed to purchase seasonal capacity in specified amounts from the other owners of the plant. Roseton generation, therefore, constitutes a substantial share of capacity utilized to serve Central Hudson's customers.

The contention is made on page C-24 of the DES, that Central Hudson could maintain adequate reserve margins through 1980 without Roseton, except in 1978; and that in 1981 and beyond, the contribution from Roseton is required to maintain these reserves.

This contention is erroneous and misleading. A review of Central Hudson's currently approved load and capacity projection shows that, without Roseton, very substantial generation deficiencies will occur in the Central Hudson system. This erroneous conclusion seemingly developed from a lack of understanding by the authors of the DES of the contract purchases from Con Edison and Niagara Mohawk. These purchases are based on purchases of Roseton generation through agreement with the other owners of the Roseton Plant. The elimination of Roseton for use by Central Hudson not only eliminates the use of its share of ownership in the plant, but the use of its committed seasonal purchases from the joint tenants. The sum of these two portions of Roseton generation, if removed from Central Hudson's load and capacity schedule, would produce extremely large deficiencies. It would be expensive for Central Hudson's consumers if Central Hudson had to purchase generation to make up for the loss of generation from Roseton.

Response

An examination of Central Hudson's long-range plans developed subsequently to the 1976 plan (New York Power Pool, 1977; 1978; 1979) confirms the observation made in this comment that capability schedules including net capacity transactions among members of the New York Power Pool are modified periodically in response to updated predictions of peak load and other pertinent factors. Information on the 1976 plan given in Table C-4 in Appendix C of the DES indicates that net capacity transactions make up a considerable portion (20 to 30 percent) of Central Hudson's total capability through the year 1980. The data given applies to the winter months since predictions made at that time showed a somewhat higher peak load occurring in winter than in the preceding summer.

Plans developed in later years show substantive changes from the 1976 plan. The 1979, or latest plan indicates that the Central Hudson system will be a net exporter of power in the winters of 1980-81, 1981-1882 and 1982-1983 and that net purchases of power will make up 14 to 25 percent of Central Hudson's total capability in the summers of 1979 through 1982 (New York Power Pool, 1979). Projection now indicate that the system will be summer peaking although the peak loads experienced each summer will not be vastly greater than the peak load experienced during the following winter.

A part of Central Hudson's summer purchases of capacity will be from the Niagara Mohawk System (New York Power Pool, 1979) and could be derived directly from the Roseton Generating Station. Clearly, this capacity would no longer be available for purchase if the operation of the Roseton station were to be considered adequate for present purposes to assume that replacement capacity would be made available from other sources within the Pool. The major thrust of the present comment appears to be that electrical energy generated by the replacement capacity would be more costly than energy generated by the Roseton facility. This point has been discussed in response to previous comments.

Comment 19-127

Furthermore, the DES implies a similar situation at Bowline. If those units are removed from service, the apparent reserves drop drastically and any opportunity to purchase capacity would only be from old, inefficient units or from gas turbines. Such an alternative, and its drastic economic impact on consumers in the Hudson Valley, is not worthy of suggestion.

Response

Responses to previous comments effectively address the point raised in this comment.

Comment 19-128

Generation planning by Central Hudson, in conformance with the target plan of the Power Pool, allows for the situation which would exist if units were delayed, thus recognizing one of the contingencies described previously. While the potential for excess capacity exists, reserve levels are believed to be within reason and to conform to the Pool concept.

Central Hudson, relying solely on oil fuel, must seek ways to minimize the economic impact of energy costs on its customers by reducing, to the extent possible, the cost of energy. The solution at hand is to operate the Roseton plant for the economic benefit ot its customers and, to the degree that it is able, to sell energy from this plant to other utilities facing higher production costs.

Provision of capacity to meet load requires an analysis of the kind and character of generation facilities and their overall costs. One cannot simply add and subtract numbers on a load and capacity sheet and thereby arrive at a conclusion about overall society benefit.

Therefore, it is believed that the DES, through a misreading of available data, has reached the the erroneous conclusion that Roseton will not be required for the benefit of customers and that substitute capacity may be secured from the Pool until 1981. A correct understanding and evaluation of the data should reach the opposite conclusion.

The correct conclusions are:

1) That Roseton is a more modern and efficient and less costly plant to run than many presently owned by the members of the Power Pool;

2) That Roseton constitutes a substantial portion of the installed capacity of the Pool and not running it will reduce the reliability of the Pool;

3) That Roseton capacity forms a large portion of generation available to Central Hudson and, in the absence of Roseton capacity, Central Hudson would be forced to purchase large blocks of capacity and energy;

4) That substitute capacity would be expensive relative to the operation of Roseton and would be a substantial economic burden on the consumers of the Hudson Valley;

5) That Roseton capacity is some of the least expensive capacity owned by Con Edison and must be run for its account to alleviate the costs of electricity in the metropolitan area;

6) That Roseton capacity and operation produces socio-economic benefits to a broad population and is particulary helpful to the customers of Central Hudson; and because of its relatively lower fuel cost, Roseton should be run as much as economically possible to maximize its benefits.

Response

These conclusions essentially summarize the comments made previously in connection with the need for the Roseton station. No further response is given here.

Comment 19-129

As to the Bowline Plant and Orange and Rockland Participation;

In Appendix C, the Corps has superficially developed charts C-6 and C-7 showing Orange and Rockland, Central Hudson and Con Edison's capacity and reserve generation with and without Bowline and Roseton capacity. These incorrect tables cannot be used when reviewing the present capability of the companies. In Table C-7, for example, the Corps indicates that Bowline accounted for 53.5% of the total energy of the Orange and Rockland system in 1975. This is far in excess of the percentage of the total Orange and Rockland generating capability represented by Bowline capacity. In 1975, Bowline generation consisted of 38% of the Orange and Rockland installed and contracted capacity. Thus, Table C-7 clearly shows that the generation from Bowline for the Orange and Rockland system is considerably in excess of the Bowline percentage of capability. Table C-6 is a superficial compilation which ignores the fact that the Bowline generation (in megawatt hours) to the Orange and Rockland system is considerably more than Bowline's percentage of capacity for the Orange and Rockland system. This indicates that Bowline is a base loaded, highly efficient generation source for Orange and Rockland, and that it cannot be simply ignored and deleted from Orange and Rockland capability without serious economic and electrical consequences.

Response

Tables C-6 and C-8 (not Table C-7) in Appendix C of the DES provide information on the reserve margins of the contribution of the Bowline Point and Roseton generating stations. The conclusions drawn from this information and set forth in Chapter 6 and Appendix C of the DEIS are that Orange and Rockland would be unable to maintain adequate reserves over the decade 1976 to 1985 without the Bowline Point Station, as would Central Hudson and Niagara Mohawk without the Roseton station. On the other hand, reserve margins in the larger Con Edison system as well as the New York Power Pool evidently could be maintained at acceptable levels over the same period with the loss of either the Bowline Point or the Roseton stations. It may be well to note that minor corrections have been made in the third paragraph of page C-24 of the FES to give a more accurate representation of the data contained in Table C-8.

Specific conclusions drawn from Table C-7 which relates to the Bowline Point Generating Station, are set forth in the first paragraph on page C-24 of the DES. Among these is the statement that in 1975, energy generated by the Bowline Point station represented 53.5 percent of the total energy generated by the Orange and Rockland System while capacity derived from the Bowline Point station represented 39 percent of the systems total capability and 44 percent of its base load capability

As indicated in responses to previous comments, there is no explicit statement in the analysis nor any intent to imply that the operation of the Bowline Point station could be suspended without economic penalty. With respect to interruptions in customer service, it is assumed in the analysis that resources available to the New York Power Pool would be made available to avert serious consequences.

Comment 19-130

The substitution of alternate sources of generation to replace prime energy that is suggested here and elsewhere in the DES (Chapter 6) would have substantial economic impacts on Orange and Rockland's customers. The fact is that the production cost of Bowline generation is the lowest in Orange and Rockland's system (after purchase of a small megawatt increment from the Fitzpatrick Nuclear Plant). Therefore, Bowline runs first and longest and would be the last to be taken off in a production operation. Any suggested operating mode of "last on, first off' would result in unjustifiable cost penalties to Orange and Rockland's customers.

Response

The "last-on-first-off" mode of operation of the Bowline Point Generating Station is considered in the context of possible restrictions that might be imposed on the operation of the station. For reasons stated in the DES, it is impossible, at present, to estimate with any degree of certainty the net advantages that the aquatic ecosystem would derive from restrictions of this type. As indicated, there would be monetary and energy penalties attendant to restrictions on the operation of the generating station.

Comment 19-131

The development of Tables C-6 and C-8 completely ignores the fact that each company has different daily, weekly, monthly and annual load factors; that each company has varied components of existing generation; that all companies are not allowed to burn oil with the same sulfur content; that each company has varied incremental production costs; and that each company has varied generating unit minimum load constraints due to indivudual system conditions. The only appropriate way to evaluate alternate generation expansion plans is through the systematic analysis of the entire electric system and sensible alternate plans.

Response

Tables C-6 and C-8 constitute only a part of the analysis of the need for the Bowline Point and Roseton Generating Stations. Variations in load and other pertinent factors are considered to the extent necessary to characterize (1) the benefits associated with the continued operation of the stations, (2) the costs associated with a suspension of operation of either station and (3) the benefits to the aquatic ecosystem of the Hudson River Estuary stemming from the expansion of operation of the stations. As discussed in previous comments, these benefits to the aquatic ecosystem, referred from the analysis related to striped bass are taken to be negligible if the suspension is temporary and small if the effects of a permanent suspension, or abandoment, of the stations are compared with the effects of operating the stations with closed cycle cooling.

Comment 19-132

The correct conclusions are:

1) It is totally untrue that the simple elimination of Bowline and Roseton from the capacity of the companies involved has a negligible effect on their capacity and energy capabilities and their ability to meet their loads.

2) The proposed elimination of Bowline and Roseton from the capacity of the companies involved is a gross oversimplification and ignores the fact that these plants are base loaded, low cost generation and that the elimination of their capacity would have a major impact on the capacity of the utilities involved.

3) The installation of gas turbines in the magnitudes suggested would not be an economic alternative to continued operation of Bowline for Orange and Rockland. Orange and Rockland has developed a generation expansion plan which allows for the installation of some gas turbine capacity in later years to meet deficiencies. This will result in a favorable base/peaking mix. However, the premature installation of gas turbines would preclude the achievement of an economic generation mix and result in economic penalties.

4) Technically, the substitution of peaking generation units for base load units ignores the realities, both of the long-term operating conditions of the two types of units and of system requirements for energy.

Response

These conclusions essentially summerize previous comments and no further response is given here.

Comment 19-133

In addition to the erroneous and misleading conclusions reached by the Corps regarding the planning for and operation of these plants, a comment appears on page C-31 of the DES (last line, double asterisk) concerning the review of sites along the Hudson River by the Power Authority of the State of New York, which concluded that "closed-cycle cooling was found to be a prerequisite in all nine cases".

Utilities do not believe that this "conclusion" should in any way influence the subject case for the following reasons:

1) The studies were not made with the depth of data which has become available in the subject case;

2) The economic parameters utilized by the Power Authority are different from those used by the companies involved in this case; costs incurred by the Power Authority do not have the same impact on customers as do costs of investor-owned utilities.

3) Several of the sites listed are not, by any means, equivalent to Roseton or Bowline in water availability. In fact, some are inland from the River, which in itself precludes the use of once-through cooling. Some are adjacent to shallow water, while others are in the northern reaches of the River where sufficient water does not exist to support once-through cooling.

The insertion of this reference is gratuitous and not germane to this case. Furthermore, the selection of a conclusion out of context is deceptive. This statement seems intended to bias the reader's thinking and should not be part of the environmental impact statement unless all of the facts which dictated the selection of closed-cycle cooling at the proposed Power Authority sites are also presented and shown to be equally applicable to Roseton and Bowline.

Response

The second footnote on page C-31 of the DES has been deleted.

Comment 19-134

Utilities take issue with the degree and nature of contribution of striped bass to the Atlantic fishery suggested on pp. D-9 to D-10 (for more complete information, see McFadden, 1977 at Section 7.10).

Response

This discussion has been modified in the FES to include the results reported by McFadden (1977).

Comment 19-135

Third Paragraph under Air Quality, page S-5 of Appendix E of the DEIS. The cooling towers determined to be appropriate by Central Hudson if cooling towers are for Roseton have a height of 390 feet above base elevation which is approximately 80 percent of the height assumed in the DES analysis. A modeling analysis utilizing the specified tower characteristics as to height and emission rates, conducted for Central Hudson, indicates the potential for ground level, cooling tower induced fogging during about 85 hours in a year when meteorological conditions correspond to those experienced in 1975. This analysis is included in the evidentiary material submitted to EPA Region II on July 11, 1977. A copy of this analysis has been furnished to the Corps (Central Hudson, 1977b).

Response

The correct cooling tower parameters have been used in the FEIS.

Comment 19-136

Last Paragraph under Air Quality, page S-6 of the Appendix E of the FEIS. The DES analysis assumed cooling towers approximately 30 percent higher than those specified for Roseton. In addition, the DES analysis assumed salinity levels (100 - 800 ppm) in the cooling tower makeup water, which are apparently meant to be representative of an average year when the salt front is well south of Roseton. During drought years the salt front moves north of Roseton and River salinities as high as 2,600 ppm have been observed under such conditions. Use of the lower tower height and the higher salinities representative of drought years would result in substantially higher indicated salt deposition rates.

Response

The correct cooling tower parameters and drought year salinities have been used in the FEIS.

Comment 19-137

The circulating water pumps discharge into a 12-ft.-square chamber, not a 9-ft.-square chamber as stated on page 3-8 in Appendix E of the DEIS.

Response

Comment noted.

Comment 19-138

The flow rate should be 1428 cfs, not 1462 cfs as stated on page 3-14 of Appendix E of the DEIS.

Response

Comment noted.

Comment 19-139

The maximum gross generation of Danskammer on oil firing (the case since 1971) is 494 megawatts, not 530 megawatts as stated on page D-1 of Appendix E of the DEIS.

Response

Comment noted.

Comment 19-140

The maximum generation for the total Roseton power plant was approximately 603 gross megawatts (not 110 megawatts as stated on page D-2 of Appendix E of the DEIS) during the entirety of the two simulation periods. However, the assumption that both units were never in operation at the same time is correct.

Response

Comment noted.

NATIONAL AUDUBON SOCIETY

Comment 20-1

Our position is one of total support for the findings and conclusions of Oak Ridge National Laboratory. Their analysis of work done by any number of environmental consulting firms shows that too many of these companies have done inadequate work on the Hudson.

The tragedy here is that the utilities have accepted this work as being the final word. Environmental groups have long maintained that studies done on the river under contract to the utilities were, by their very nature, flawed.

Response

A discussion of the adequacy of the data presented by Utilities regarding entrainment, impingement, and long term impacts to fish populations begins at paragraph 4. . This discussion summarizes the work of Oak Ridge National Laboratory as well as other consultants to the U.S. Environmental Protection Agency.

Comment 20-2

An example of ORNL's thoroughness can be found in their critique of work done by LMS (ORNL/TM-5877/U2 page S-8 Section S.3.5 para. 3). No coalition of environmental organizations could have funded such a study as this (ORNL).

Response

The analysis presented in the document cited, which was reproduced as part of Appendix E in the Draft Environmental Impact Statement, has been superceded by additional analysis carried out by the Oak Ridge National Laboratory and other consultants to the U.S. Environmental Protection Agency since the publication of the Draft EIS. The findings of these new analyses have been incorporated into the Final Environmental Impact Statement.

Comment 20-3

We ask that you support the findings and conclusions of the Oak Ridge National Laboratory.

Response

The Corps of Engineers will consider all relevent information in determining the appropriate decision regarding the points at issue.

NATURAL RESOURCES DEFENSE COUNCIL, INC.

Comment 21-1

The DEIS properly points out that even with sophisticated computer modeling the decision that must be made still revolves around a policy determination of how much risk to the fishery should the public be required to take.

Response

A discussion of the adequacy of the data available for determining the impact to the fishery begins at paragraph 4.

Comment 21-2

The decision, then, comes down to a judgment by the Corps of risk. Will the Corps of Engineers accept the risks presented by the power plants, plus other likely water withdrawals, when alternatives exist which, although costly, are yet well within the financial ability of utilities?

Response

The Corps of Engineers must consider all reasonable alternatives in determining the appropriate decision regarding the intake permits at issue.

Comment 21-3

The Draft EIS's major deficiency is its failure to propose a decision or state a criteria for decision. While we understand this procedure is perhaps sanctioned by CEO guidelines, it is unfortunate that in a case of such complexity the Corps did not present for public comment a proposed decision as well.

Response

An environmental impact statement is not the decision document itself, but rather is a neutral disclosure document of environmental impacts associated with a proposed action. Environmental impacts are then considered along with other relevant factors in the decision process. Corps of Engineer regulations presently prevent the stating of a decision in the impact statement.

Comment 21-4

The Utilities expressly agreed and accepted their construction permits on their agreement that the plants were to be constructed at thier risk and that there should be no consideration in the EIS of the fact that the plants were already constructed. The DEIS cost analysis is therefore incorrect when it shows retrofit costs, shutdown costs, inflationary costs, and the like. The Corps must examine costs solely as if the plants were not built and as if the cooling towers were part of a new plant.

Response

The analysis of impacts must describe the actual costs associated with the construction of cooling towers at Bowline and Roseton. Since such construction would require retrofitting the power plants as now operating, the analyses cannot pretend that such is not the case. It is true, however, that the Utilities accepted the risk that, should cooling towers be required in the future, their costs would be considerably greater.

Comment 21-5

The court order commands a decision for both Bowline Point and Roseton. The Corps cannot delay its decision.

Response

The Corps of Engineers will make a decision in accordance with the schedule required by the court.

Comment 21-6

Because the utilities are vigorously contesting cooling towers at all sites, on legal as well as factual grounds, and because the Corps cannot discount the possibility that the utilities will be successful, the Corps can consider only the worst case in evaluating risk.

Response

A worst case approach has generally been used in the analyses in the FEIS.

Comment 21-7

The action being considered by the Corps is the granting of a permit to allow construction of intake and discharge structures related to two power plants. HRFA does not oppose allowing the necessary construction but vigorously contends that adequate and available means to mitigate the volume of water withdrawals must be imposed.

Response

Comment noted. The Corps of Engineers will consider all relevant information in making its decision.

Comment 21-8

There is a substantial risk that the adult striped bass population will be reduced by more than half if Hudson River plants continue to operate as they do at present.

Response

Material submitted by the U.S. Environmental Protection Agency as testimony in the on-going adjudicatory hearings indicates that available data are generally inadequate to predict long-term impacts to adult fish populations (see discussion beginning at paragraph 4.).

Comment 21-9

Although there are huge gaps in the knowledge of effects upon other species, the available information is highly suggestive that the harm to certain species will be even greater than the harm to striped bass.

Response

See response to comment 21-8.

Comment 21-10

Compensation by the fishery has not been shown and, as evaluated by Oak Ridge, could not possibly be of the magnitude suggested by the utilities. Furthermore, there is no evidence that other means of mitigating the harm to the fishery are effective.

Response

Compensation has not been clearly demonstrated in the fish populations of the Hudson River (see paragraph 4.). Other means of reducing entrainment and impingement are possible, but studies of their effectiveness have not been carried out on the Hudson River (see Chapter 6).

Comment 21-11

The DEIS does not clearly state what is the proposed action for which it has been drafted.

Response

The actions available to the Corps of Engineers are (1) to retain unaltered the present permit and related conditions, (2) modify the permit through the imposition of additional conditions, (3) suspend the permit, or (4) revoke the permit (see paragraph 6.01).

Comment 21-12

It is one thing to ask, as the DEIS does, whether it is justified to compel the utilities to spend $100 million each for cooling towers. It is quite another to ask, in connection with allowing the construction of of beneficial power-generating plants costing $250 million each (with a replacement value of $1 billion each), whether the Corps is justified in requiring the owners to minimize environmental risks by restricting the volume of water intakes. The manner in which the issue is phrased in the the DEIS suggests that the only concern is additional restrictions rather than minimizing impacts in connection with granting the overall application.

Response

The duty of the Corps of Engineers is to evaluate the impacts associated with the operation of the Bowline Point and Roseton Generating Stations in conjunction with other power plants on the Hudson River. The decision of the Corps must be that which best serves the public interest. The options available to the Corps in deciding on the appropriate action to take on the permit request for placing of cooling water intake structures in navigable waters have been given above in the response to Comment 21-11.

Comment 21-13

The need to minimize withdrawals of water is established in the showing of the severe environmental risks in the DEIS. This is so even with the DEIS's failure to quantify even minimally the risk to the fishery from once-through cooling.

Response

The Corps of Engineers disagrees that no attempt has been made in the EIS to quantify the risk to the fishery. The difficulty in carrying out such an analysis has been discussed beginning at paragraph 4.

Comment 21-14

The Corps should allow the permit, but condition the construction to limit the water withdrawals in order to minimize the substantial environmental impacts of the impingement, entrainment, and thermal discharge.

Response

Comment noted.

SAVE OUR STRIPERS, INC.

Comment 22-1

Computer modelling: Computers are excellent tools but they only do what the human programmer tells them to do. All model projections should be considered suspect because in most cases the data are from only two years. The model fails to account for peaks and valleys in the cycles and in most cases the model did not take into consideration all the plants that affect the species.

Response

The Utilities Real-Time Life Cycle model and the U.S. Environmental Protection Agency Empirical Transport Model include the effect of all power plants that have the largest potential for effecting striped bass eggs, larvae, and juveniles. The utilities model incorporates stochiastic model events into the model. A discussion of the usefulness of these modeling efforts begins at paragraph 4.

Comment 22-2

The two major problems are Indian Point and Bowline. Insisting that these two have closed-cycle cooling systems would solve the bulk of the problem.

Response

Comment noted.

Comment 22-3

The independently sought data points in the direction of closed cycle cooling in one form or another. Dry cooling seems to be impractical for large plants, but evaporative systems would seem to do well. We believe that on the strength of existing evidence some form of closed-cycle cooling system for Bowline and Indian Point is absolutely necessary.

Response

The environmental impacts of use of evaporative cooling towers is discussed in the FES beginning at paragraph 4.85 .

Comment 22-4

As much thought should be given to the protection of other species and habitats in the Hudson as you have for the striped bass. Sections two and four show that power plants are affecting wetlands, plankton productivity, and other fish such as anchovies which may have an effect on total food supply available for striped bass. (Sections 2-33, 2-56, 2-58, 4-110, 4-57, 4-64, 4-66, etc.)

Response

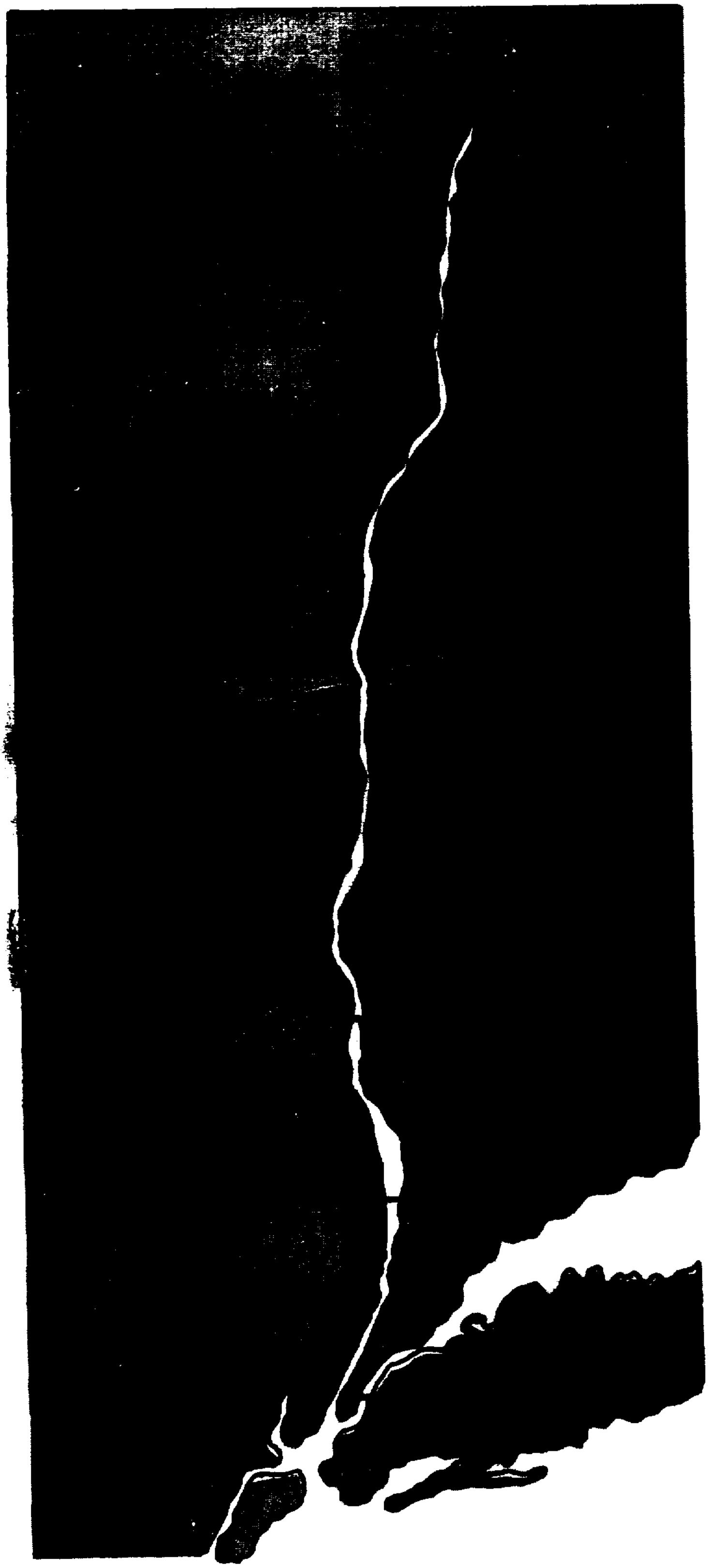
Total loss of wetland areas from construction of existing power plants is not known, but 60 acres were filled in construction of the Bowline station (see paragraph 4.112 of the FES). Impacts to phytoplankton productivity are expected to be slight (see paragraph 4.163of the FES). Presently available data on impacts to white perch, Atlantic tomcod, American shad, Blueback herring, and shortnose sturgeon are discussed beginning at paragraph 4.173 of the FES.

Comment 22-5

Texas Instruments studies comparing the relative contributions of the Hudson River and Cheasapeake Bay to the Atlantic fishery should not be used as an argument to attempt to dismiss the Hudson River's contribution as unimportant. Chesapeake production has been exceptionally poor since 1970. In this light the Hudson's contribution is of vast importance.

Response

A revised analysis of the contribution of Hudson River striped bass to the Atlantic fishery is given in the FES beginning at paragraph 4.242.



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DEPARTMENT OF THE ARMY
NEW YORK DISTRICT
CORPS OF ENGINEERS
26 FEDERAL PLAZA
NEW YORK, N.Y. 10278

FINAL ENVIRONMENTAL IMPACT STATEMENT

JAN. 1981

BOWLINE POINT GENERATING STATION

Haverstraw, New York

DEPARTMENT OF THE ARMY
NEW YORK DISTRICT
CORPS OF ENGINEERS
26 FEDERAL PLAZA
NEW YORK, N.Y. 10278

SUMMARY

BOWLINE POINT GENERATING STATION
HAVERSTRAW, NEW YORK

( ) Draft (XX) Final Environmental Statement

Responsible Office: Department of the Army
New York District, Corps of Engineers
26 Federal Plaza
New York, N.Y. 10007

1. Nature of Action: (XX) Administrative ( ) Legislative

2. Description of Action

The New York District, Corps of Engineers is considering several alternative actions in connection with the continued operation of the Bowline Point and Roseton Generating Stations. Both stations are in full commercial operation within the electrical supply system of the New York Power Pool. Permits authorizing the construction of intake and discharge structures and other activities related to the construction of these stations were issued by the District in 1970 and 1971. The District now has legal obligations to evaluate the environmental impacts of the Bowline Point and Roseton Generating Stations and to determine the appropriate course of action regarding their continued operation. Alternatives available to the District are (1) to retain unaltered, (2) to modify, (3) to suspend or (4) to revoke the permits issued by the District.

3a. Environmental Impacts

The environmental impacts associated with each of the alternatives enumerated above are described in the present statement. The analysis of impacts encompasses the cumulative effects associated with all existing power plants on the Hudson River. In the analysis of cumulative effects, particular attention is directed towards the Bowline Point and Roseton Generating Stations, both 1,200 megawatt oil-fueled power plants on the Hudson River located, respectively, at Haverstraw and Newburgh, New York.

Operation of the Bowline Point and Roseton power plants entails the consumption of fuel oil and the withdrawal of water from the Hudson River for condenser cooling and other station purposes. Both stations release airborne and waterborne contaminants and generate noise and small quantities of solid wastes. The power plants are conspicuous features in their respective settings. Substantial property taxes accrue to the localities in which the generating stations are situated.

3b. Adverse Environmental Impacts

Concern over the power plants sited on the Hudson River has centered primarily on potential adverse impacts on the aquatic ecosystem resulting from the operation of these plants. Impacts are associated principally with the entertainment of fish eggs and larvae through the power plant cooling systems and the impingement of juvenile fish on devices used to screen the water at the condenser intakes. Extensive research and field surveys over the past several years have been oriented heavily towards potential effects on striped bass (Monroe saxatilis). Notwithstanding these efforts, the extent to which the adult fish stocks within the Hudson River might be reduced if all existing power plants continue to operate with once-through cooling systems remains a matter of controversy. Staff members of the Utilities and their consultants have estimated the long-term reduction of adult stocks of several fish species to be as follows:

Striped bass - 2.6 to 10.8 percent
White perch - 0.2 to 14.0 percent
American shad- 0.1 to 4.0 percent

The staff of the U.S. Environmental Protection Agency, Region II and their consultants have reviewed the Utilities analyses. They have concluded that there are sufficient uncertainties about the quality of the data from the Hudson River and the applicability of the theory of population dynamics which is the Utilities' basis for predicting long-term impacts to cast considerable doubt on the validity of the entire Utilities' analysis. The staff of the U.S. Environmental Protection Agency has made no estimates of their own of the magnitude of potential long term impacts to fish populations, but analyses carried out by their consultants indicate that reductions in fish populations could be much greater than those predicted by the Utilities. The installation of evaporative close-cycle cooling systems at certain power plants on the river would reduce but not entirely eliminate the destruction of aquatic organisms from entrainment and impingement.

Monitoring of air quality in the area surrounding the Bowline Point station has revealed no instance when the ambient air quality standards of New York State have been exceeded since the initial operation of the plant. Monitoring at the Roseton station has shown that the New York State standards for ambient concentrations of sulfur dioxide are being exceeded occasionally. In addition, the Federal secondary standard for suspended particulates is being exceeded occasionally. Numerical simulations show no evidence of substantive cumulative effects on ambient air quality arising from the operation of the power plants on the Hudson River.

Numerical simulations indicate that water temperatures in excess of New York State criteria could occur in the Hudson River as a result of the cumulative thermal discharges from existing and proposed power plants.

Installation of closed-cycle cooling systems at the Bowline Point and Roseton stations would increase noise levels off site. In addition, the use of cooling towers could potentially cause icing and fogging in their vicinities and the formation of acidic mist from interactions of the tower plume and stack emissions, although the probability of these events occurring is expected to be low. The potential exists for damage to vegetation from salt drift from a cooling tower at the Bowline Point station but is unlikely in the vicinity of the Roseton station. The visibility of the power stations would be increased substantially by closed-cycle cooling systems, particularly if natural draft towers are installed.

4. Alternatives

Alternative actions that might be implemented with respect to the continued operation of either or both the Bowline Point and the Roseton generating stations are:

with the
existing
intake +
discharge
structures

(1) To retain unaltered the permit and related conditions as issued by the District,
(2) To modify the permit through the imposition of additional conditions relating to the operation of the station,
(3) To suspend the permit until closed-cycle cooling or other modifications are installed,
(4) To revoke the permit, forcing the abandonment of the station.

5. Comments on the Draft Environmental Statement Requested From

Federal Agencies

Advisory Council on Historic Preservation
Department of Agriculture
Department of Commerce
Department of Health, Education and Welfare
Department of Housing and Urban Development
Department of the Interior
Department of Transportation
Energy Research and Development Administration
Environmental Protection Agency
Federal Power Commission
Nuclear Regulatory Commission
Office of Economic Opportunity

New York State

New York State Department of Environmental Conservation
New York State Department of Parks and Recreation
New York State Department of Transportation
New York State Planning and Development Clearinghouse
Power Authority of the State of New York
Public Service Commission

Other Parties

Central Hudson Gas and Electric Corporation
Consolidated Edison Company of New York, Inc.
Environmental Defense Fund
Haverstraw Town Clerk
Haverstraw Village Clerk
Hudson River Fishermen's Association
Hudson River Sloop Restoration, Inc.
Hudson Valley Audubon Society
Interstate Sanitation Commission
Mid-Hudson Pattern for Progress, Inc.
National Audubon Society
Natural Resources Defense Council, Inc.
Niagara Mohawk Power Corporation
Oak Ridge National Laboratories
Orange and Rockland Utilities, Inc.
Port Authority of New York and New Jersey, Planning and Development Department
Regional Plan Association
Rockland County Clerk
Rockland County Department of Health
Rockland County Planning Board
Save Our Stripers, Inc.
Stony Point Town Clerk
Town of Haverstraw Planning Board
Tri-State Regional Planning Commission
Village of Haverstraw Planning Board
West Haverstraw Village Clerk

County Planning Departments

New York: Albany, Rensselaer, Greene, Columbia, Ulster, Dutchess, Orange, Putnam, Rockland, Westchester

New Jersey: Bergen, Hudson

6. Draft Environmental Statement filed with the Council on Environmental Quality on ______________.

7. Comments on the Draft Environmental Statement Received From

Federal Agencies

Department of Agriculture, Forest Service
Department of Agriculture, Soil Conservation Service
Department of Commerce, Assistant Secretary for Science and Technology
Environmental Protection Agency, Region II
Department of Health, Education and Welfare, Office of the Secretary
Department of Health, Education and Welfare, Region II
Department of Housing and Urban Development, Area Office
Department of the Interior, Office of the Secretary
Department of Transportation, Federal Highway Administration
Department of Transportation, Regional Representative of the Secretary

State of New York

Department of Environmental Conservation
Department of Law
Metropolitan Transportation Authority

Utilities

Central Hudson Gas and Electric Corporation
Consolidated Edison Company of New York, Inc.
Orange and Rockland Utilities, Inc.

Other Parties

National Audubon Society
Natural Resources Defense Council, Inc. on behalf of the Hudson River Fisherman's Association
Save Our Stripers, Inc.

8. Final Environmental Statement Filed with the U.S. Environmental Protection Agency on ____________.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

Page

U.S. Department of Health, Education and Welfare, Office of the Secretary

U.S. Department of the Interior, Office of the Secretary

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Concluded)

LIST OF FIGURES

LIST OF FIGURES (con't)

LIST OF FIGURES (CONCLUDED)

LIST OF TABLES

LIST OF TABLES (con't)

LIST OF TABLES (con't)

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LIST OF TABLES (CONCLUDED)

CHAPTER 1

PROJECT DESCRIPTION

1.01 This environmental impact statement relates principally to the operation of the Bowline Point Generating Station, a power plant located on the Hudson River in Haverstraw, New York. Consideration is given to the impacts associated with the Bowline Point station and to the cumulative impacts of all existing, projects on the river. The analysis presented in this report focuses also on the Roseton Generating Station, a second plant in commercial service located in Newburgh, New York. The U.S. Army, Corps of Engineers, New York District (the District) has legal responsibilities to review the impacts of operating the Bowline Point and the Roseton generating stations and, in each instance, to determine the appropriate course of action regarding the continued operation of these stations.

1.02 For the past several years, concern has been expressed over the operation of power plants sited along the Hudson River. This concern centers mainly on the potential adverse effects that each plant may exert individually on populations of striped bass and other fishes of the Hudson River as well as the combined effects of all of these power plants. Accordingly, the District, in assessing the environmental impacts resulting from the operation of the subject power plants, has devoted particular attention to matters relating to alternations of the aquatic ecosystem of the Hudson River and to the cumulative and synergistic effects that may arise from the operation of existing plants and future developments on the river.

NATURE OF PROJECT AND AUTHORITY

1.03 The Bowline Point Generating Station is located in the Village of West Haverstraw and the Town of Haverstraw, Rockland County, New York. The station consists of two oil-fueled steam electric generating units and related facilities, constructed by Orange and Rockland Utilities, Inc. (referred to as Orange and Rockland throughout this document). The generating units, designated Units No. 1 and No. 2, are each rate at a nominal 600 megawatts* and are currently in commercial service. The Bowline Point Generating Station is owned jointly by Orange and Rockland and Consolidated Edison Company of New York (Con Edison).

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*Unless otherwise specified, the term megawatt denotes megawatt-electric throughout this document.

1.04 On 18 February 1970, Orange and Rockland applied to the District for a Department of the Army permit under Section 10 of the River and Harbor Act of 1899 (30 Stat. 1151; 33 U.S.C. 403), seeking authorization to dredge an inlet channel, to install discharge piping and construct a mooring facility, all in the navigable waters of the Hudson River in Rockland County, New York. The District prepared and circulated a draft environmental statement (filed with the Council on Environmental Quality on 4 October 1972) relating to the proposed work. The District subsequently revised and recirculated the draft environmental statement on 23 August 1973.

1.05 The District issued the requested permit on 12 July 1971. Construction work on Bowline Point Unit No. 1 was completed and the unit was brought into commercial service in September 1972. Unit No. 2 was brought into commercial service in May 1974.

1.06 On 29 December 1972, the Hudson River Fishermen's Association, Inc., together with other plaintiffs, filed a complaint in U.S. District Court, Southern District of New York (the Court) alleging that the withdrawal of water by the Bowline Point units for condenser cooling purposes would result in serious damage to the environment, including the entrainment of substantial numbers of striped bass eggs, larvae and juveniles. The plaintiffs alleged further that the District had wrongfully issued the above mentioned permit in that its issuance had not been preceded by the submission of a final environmental impact statement in accordance with the requirement of the National Environmental Policy Act of 1969 (42 USC, 4321 et seq.).

1.07 On 9 January 1974, the Court sanctioned a consent decree entered by consent of the Hudson River Fishermen's Association and the District, together with Orange and Rockland and Con Edison. In accordance with the terms of the decree, certain restrictions were imposed on the operation of the Bowline Point Units No. 1 and No. 2 during the last 10 days in May and the months of June and July of 1974. Further, the District agreed to prepare and circulate a draft environmental statement related to the construction and operation of the Bowline Point Generating Station, considered in conjunction with other existing and proposed facilities on the Hudson River. In response to this provision, the District has sponsored a study* by the Oak Ridge National Laboratory to evaluate the effects of the Bowline Point station and cumulative effects on (1) the population of stripped bass in the Hudson River, taking into account information that has become available since the issuance in 1972 of the U.S.

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*A Selective Analysis of Power Plant Operation on the Hudson River with Emphasis on the Bowline Point Generating Station, Oak Ridge National Laboratory, ORNL/TM-5877, June 1977.

Atomic Energy Commission's environmental statement concerning the Indian Point Generating Station, (2) the thermal regime of the Hudson River and (3) regional air quality. In addition, the present final environmental statement* has been developed to incorporate the major findings of the study undertaken by the Oak Ridge National Laboratory and to present the District's analysis of other related impacts. The full text of the consent decree is included in Appendix B.**

1.08 A related legal action concerns the Roseton Generating Station Units No. 1 and No. 2 located in the Village of Roseton, Town of Newburgh, Orange County, New York. The station comprises two fossil-fueled units, with a nominal combined capacity of 1,200 megawatts, constructed by Central Hudson Gas and Electric Corporation (Central Hudson) and owned jointly by Central Hudson, Con Edison and Niagara Mohawk Power Corporation (Niagara Mohawk). On 29 December 1972, the Hudson River Fishermen's Association and other plaintiffs filed a complaint in U.S. District Court, Southern District of New York, alleging that the withdrawal of water by the Roseton Generating Station for condenser cooling purposes would result in serious damage to the environment, including the entrainment of substantial numbers of striped bass eggs, larvae and juveniles. The plaintiffs alleged further that the District had wrongfully issued a Department of the Army permit under Section 10 of the River and Harbor Act of 1899, authorizing Central Hudson on 13 March 1970 (with later amendment of the permit on 20 December 1971) to construct within the navigable waters of the Hudson River certain facilities related to the Roseton Generating Station, in that issuance of this permit had not been preceded by the submission of an environmental impact statement in accordance with the requirements of the National Environmental Policy Act of 1969.

1.09 On 25 July 1974, the Court sanctioned a consent decree entered by consent of the Hudson River Fishermen's Association and the District, together with Central Hudson, Con Edison and Niagara Mohawk. Under the terms of the decree, the District is required to review and evaluate the construction and operation of the Roseton Generating Station and to determine whether suspension, modification or revocation of the permit may be necessary for the protection of the fish and wildlife resources of the Hudson River. The study and

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*This document is derived, in part, from a draft environmental statement submitted to the Council on Environmental Quality on 23 August 1974, and from an uncirculated final environmental statement prepared by the District in January 1976.

**Appendix A is reserved for comments to this draft environmental statement.

evaluation are to be based on: 1) information and data developed by the District in preparing the environmental impact statement relating to the Bowline Point Generating Station 2) information and data pertinent to Con Edison's application to the District for a permit authorizing dredge and fill work connected with the proposed pumped storage facility at Cornwall, New York, and 3) the review and comments on the draft statement by the plaintiffs in the Roseton action, the Department of the Interior, the National Marine Fisheries Service, the Environmental Protection Agency, the regulatory staff of the Atomic Energy Commission (now the Nuclear Regulatory Commission), the New York State Department of Environmental Conservation and other persons or governmental agencies. The full text of this second consent decree is included in Appendix B.

BOWLINE POINT GENERATING STATION*

1.10 The Bowline Point Generating Station is sited on the west bank of the Hudson River at (River) Mile Point 38 north of the Battery in Manhattan, New York City. A view of the Bowline Point Generating Station from the Hudson River is given in Figure 1-1 and a plot plan of the station in Figure 1-2. The site extends over 245 acres and encompasses the 53-acre Bowline Pond. Prominent features of the station include the central power plant complex, a fuel oil storage facility, a marine terminal and a recreational facility located immediately to the east of Bowline Pond and north of the pond inlet.

Power Generating Equipment

1.11 The Bowline Point Generating Station comprises two oil-fueled steam electric generating units of conventional modern design, each rated at a nominal 600 megawatts. Each unit consists of a steam generator, a turbine generator and associated auxiliary and control equipment.

1.12 Combustion Engineering, Inc. supplied the steam generator for Unit 1, and the Babcock and Wilcox Company supplied the steam generator for Unit 2. Both turbine generators were supplied by the

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*Material in this section is derived from a description of the Bowline Point project (Orange and Rockland, March 1971) prepared for Orange and Rockland by Bechtel Associates. Updated information based on operating experience has been provided by Orange and Rockland. Supplementary information on the Bowline Point Generating Station and certain other facilities sited along the Hudson River was gathered during a visit of the facilities on 3 and 4 November 1976 and subsequent requests for additional information from the operators of the generating stations on the Hudson River.

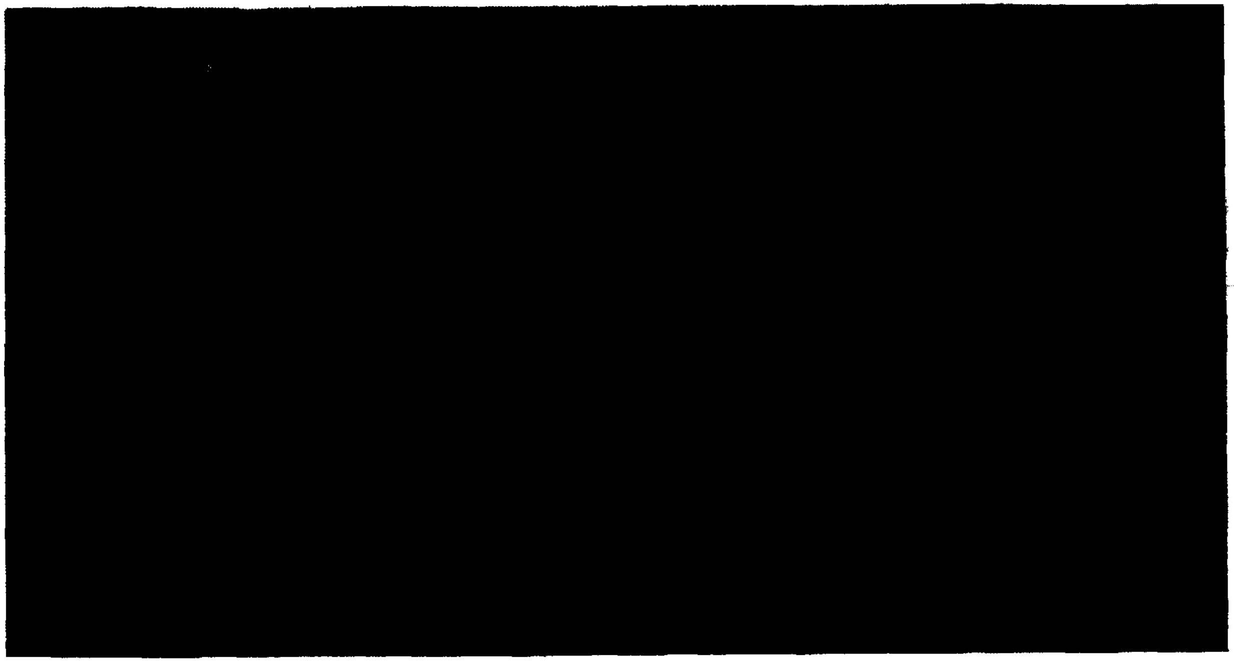
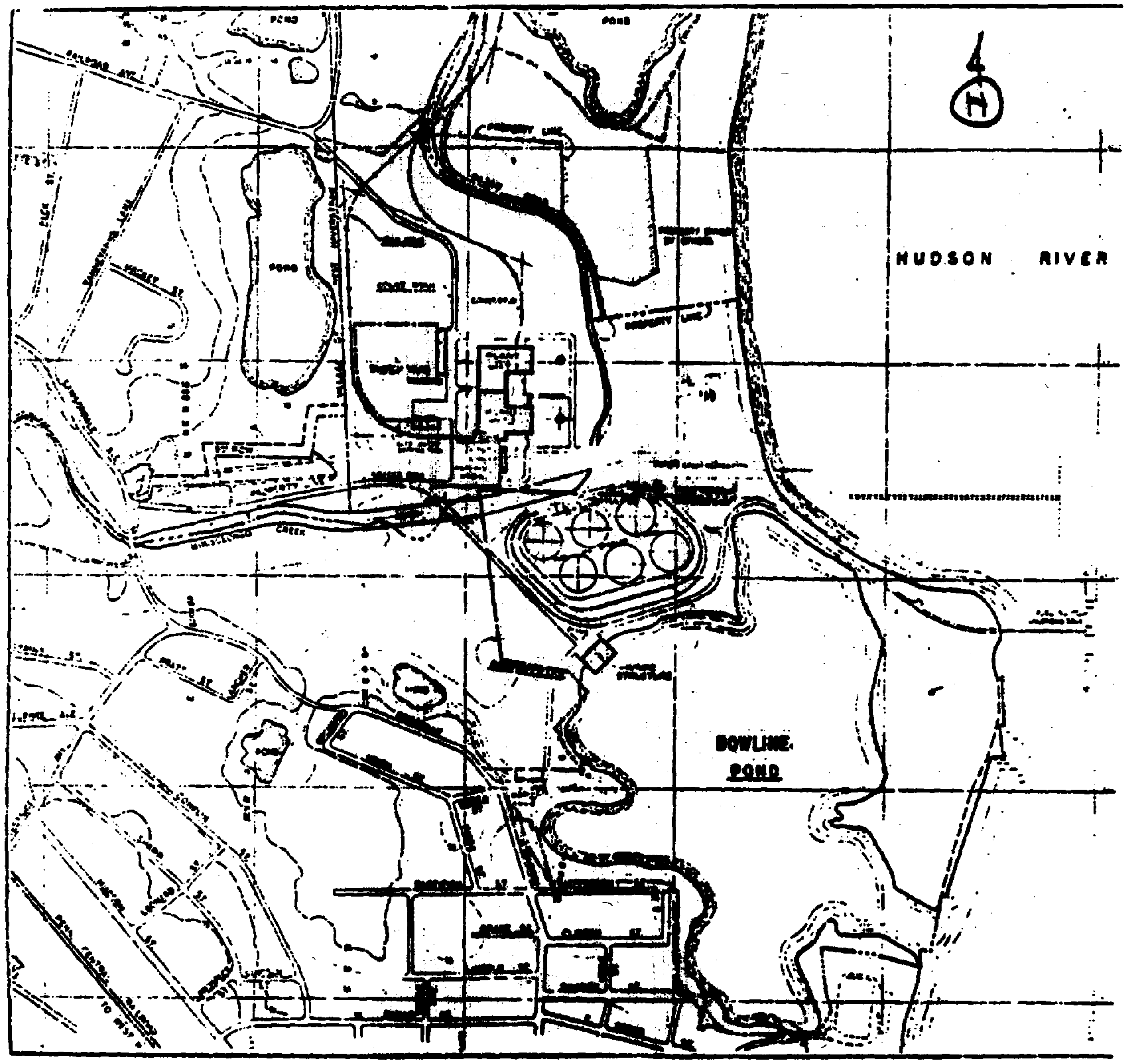


FIGURE 1-1

THE BOWLINE POINT GENERATING STATION VIEWED FROM THE HUDSON RIVER



Source: Orange and Rockland, March 1971.

FIGURE 1-2

PLOT PLAN OF THE BOWLINE POINT GENERATING STATION

General Electric Company. Although the units differ in certain technical details, they are practically identical in all aspects relating to their interaction with the environment and are treated accordingly throughout this analysis.

1.13 The generating units operate a steam cycle with a single stage of reheat of the main steam and six stages of feedwater heating. Each steam generator includes a water cooled furnace, superheater, reheater, economiser, regenerative air heaters, soot blowing equipment, burner and ignition control assemblies, and integrated control system. The steam generators are designed to deliver at maximum continuous rating 4.20 million pounds of steam per hour at 1005°F at the superheater outlet and 3.79 million pounds of steam per hours at 1005° at the reheater outlet. The maximum guaranteed superheater outlet pressure is 2600 pounds per square inch guage. The thermal efficiency of the steam generator exceeds 89 percent.

1.14 Each turbine generator has a nominal nameplate capacity of 555 megawatts at nominal throttle steam conditions of 2,400 pounds per square inch guage and 1000°F, with reheat to 1000°F. The turbine generators are tandem compound, four flow condensing reheat units, designed to operate at 3,600 revolutions per minute.

1.15 Operation of plant auxiliary equipment such as pumps, fans and impellers entails the consumption of electrical energy at a rate of approximately 21 megawatts. The net station capability (power delivered to the transmission line leaving the station) under normal, full power operating conditions is 1,201 megawatts. The overall thermal efficiency of the plant is 35.6 percent, corresponding to a net plant heat rate of 9,600 BTU per kilowatt-hour.

Fuel Supply

1.16 The Bowline Point generating units are designed to burn fuel oil and natural gas as an alternative fuel. With substantial modifications, the units could be converted to burn coal. Facilities would have to be provided to receive, handle and pulverize the coal feed and structural changes would have to be made to handle the increased ash load. Equipment would have to retrofitted to control the emission of airborne particulate matter. Since the plant has not been designed ~~or constructed to burn coal, it is not subject to~~ prohibition from burning petroleum products by the Federal Energy ~~Administration~~ pursuant to Section 2 of the Energy Supply and ~~Environmental Coordination~~ Act of 1974 (P.L. 93-319 as amended by P.L. 94-163).

1.17 The station currently burns #6 fuel oil supplied under a long-term agreement by New England Petroleum Corporation, Amerada-Hess Corporation and Asiatic Petroleum Corporation. In accordance with the conditions of the supply contract; the sulfur content of of the fuel oil is limited to 0.37 percent by weight or less. The ash content of the fuel oil is 0.02 percent and its average heating value is 5.77 million BTU per barrel.

1.18 The consumption rate of fuel oil with both units operating at full power is 1,897 barrels per hour. This corresponds to a maximum daily (24 hours) consumption rate of approximately 30,000 barrels and an annual consumption of 10 million barrels at an overall plant load factor of 0.66. The aggregate storage capacity provided on site is 810,000 barrels, which is, an adequate reserve to operate both units at full power for 17 days. In normal circumstances, the reserve is replenished every 1.5 days by supply barges of 55,000 barrel capacity.

Cooling System

1.19 The Bowline Point Station currently operates with a once-through or open cycle condenser cooling system. While either one of the generating units is in operation, cooling water is withdrawn continuously from Bowline Pond, circulated through the main condenser and discharged to the Hudson River through submerged diffusers.

this is not correct

1.20 Each of the two plant condensers is designed to reject heat at the rate of 2.79 billion BTU per hour at a flow rate of 375,000 gallons per minute and a temperature rise of 15F. In actual practice a flow rate of 316,000 gallons per minute is maintained through each condenser and the average temperature rise is 13.5F at full power operation. The corresponding heat rejection rate is 2.14 billion BTU per hour from each unit.

one motor — no?

1.21 A battery of six pumps, each rated at 128,000 gallons per minute and equipped with a 1,500-horsepower motor, supplies cooling water to the plant condensers. The pumps are arranged in two independent sets of three pumps, one set serving each of the generating units. Under normal conditions, two pumps per set are kept running while the corresponding unit is in operation. The third pump would be on standby or undergoing maintenance. The pumps are housed in the intake structure on Bowline Pond.

1.22 Cooling water is pumped a distance of approximately 1,600 feet through two underground 126-inch diameter pipes to the condensers located in the main plant. The heated water leaves the system through two underground 126-inch pipes that terminate in diffusers approximately 1,300 feet offshore on the river bottom. The overall pipe length from the condensers to the diffusers is about 2,850 feet. The underwater portions of the discharge line are supported on steel pile bents driven into glacial till approximately

130 feet below the surface of the river to ensure stability of the line with respect to both alignment and elevation.

1.23 Provisions have been made to recirculate a portion of the cooling water discharge back to Bowline Pond as a means of preventing ice blockage of the intake in severe weather.

Power Buildings and Facilities

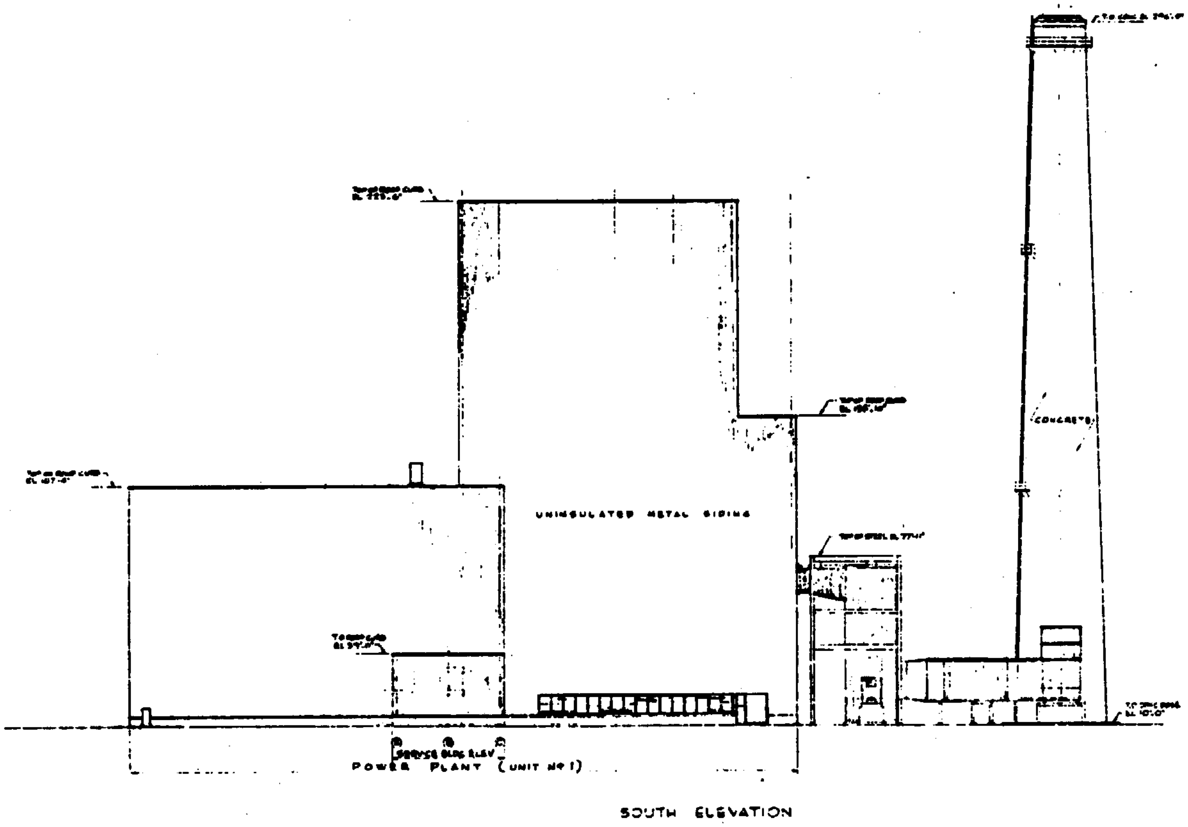
1.24 The main plant buildings house the steam generators, steam turbines, electric generators and associated equipment. The south and east (riverfront) elevations of the buildings are shown in Figures 1-3 and 1.4. The roofs of the two steam generator sections of the plant and the roof of the turbine-generator section are, respectively, 214 feet and 97 feet above plant grade. The main building is 460 feet long and 273 feet wide. The building exterior is clad with ribbed metal siding, permanently finished in medium brown.

1.25 Two concrete stacks, measuring 287.5 feet in height and 37 feet in base diameter, are located 110.5 feet east of the power building, with a center-to-center separation of 286 feet. Aircraft warning lights are present on each of the stacks.

1.26 A two-story service building immediately south of the main plant provides space and facilities for administrative, clerical and laboratory support functions. The structure serves both Units 1 and 2 and is connected to the main plant building by sidewalks at ground level and an enclosed bridge on the second floor. The service building is 115 feet long, 46 feet wide and 29 feet high.

1.27 A warehouse serves as a central storage area for equipment, materials and supplies. The warehouse is 220 feet long, 50 feet wide, 16 feet high and is located approximately 127 feet to the west of the main plant, immediately adjacent to the switchyard. A building, about 200 feet south of the warehouse contains shop and other maintenance facilities. The shop building is 140 feet long, 50 feet wide and 16 feet high.

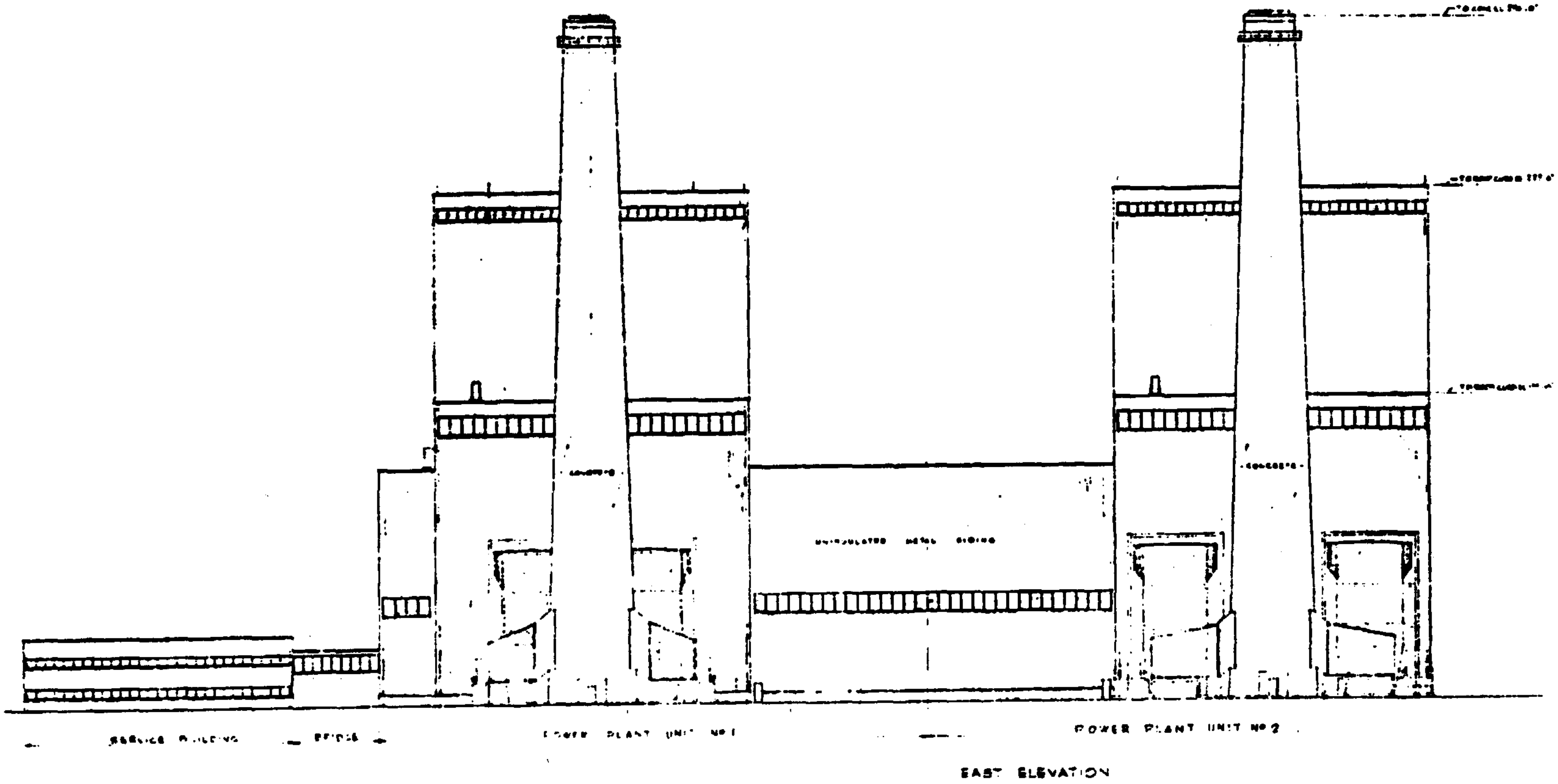
1.28 The station switchyard accommodates the main transformers, towers, electrical buses, breakers and related equipment necessary to deliver the electrical power generated by Units 1 and 2 to Orange and Rockland's transmission network. The switchhouse, consisting of meter and relay rooms, is located in the south end of the warehouse building.



Source: Orange and Rockland, March 1971.

FIGURE 1-3

BOWLINE POINT GENERATING STATION--SOUTH ELEVATION



Source: Orange and Rockland, March 1971.

FIGURE 1-4
BOWLINE POINT GENERATING STATION--EAST ELEVATION

Fuel Oil Storage Facility

1.29 Six fuel oil tanks, each of 145,000-barrel capacity (135,000-barrel operating capacity), are located within an 8-acre tract surrounded by a berm immediately north of Bowline Pond and adjacent to the south bank of Minisceongo Creek. Sufficient fuel oil can be stored to allow both Units 1 and 2 to operate at full power for a period of approximately 17 days, ensuring a continuity of power generation in the event of a temporary disruption in fuel oil delivery. A fuel oil pumphouse, measuring 50 feet in length and 38 feet in width, is recessed into the berm on the north side and houses pumps to transfer fuel oil to the power plant. Also housed in the pump structure is a portion of the fire protection system as well as a surface water drainage sump designed to minimize the discharge of oily waters into Minisceongo Creek and the Hudson River.

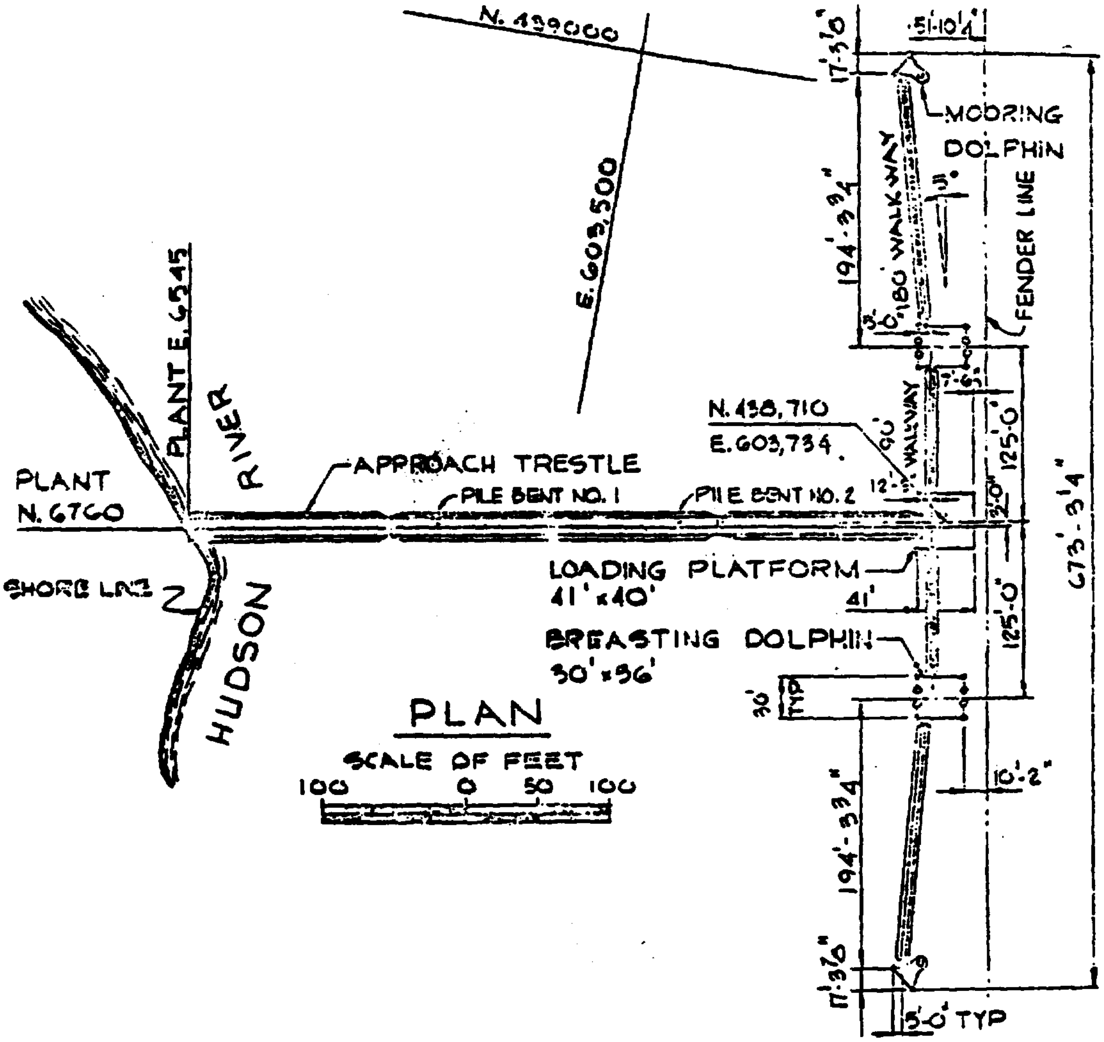
1.30 The berm serves the dual purpose of providing containment in the event of oil leakage from any of the storage tanks and partially screening the tanks from public view. The oil tanks are cylindrical with slightly domed tops; each tank is 180 feet in diameter and 32 feet in overall height. The height of the berm varies between 10 and 28 feet. Grass has been planted on the earthern slopes of the berm.

Marine Terminal

1.31 The marine terminal is an oil receiving facility designed to accommodate barges and tankers delivering fuel oil to the plant. While tankers of up to 50,000 deadweight tons could be docked at the facility, the present depth contours of the Hudson River limit access to the terminal to barges of 100,000-barrel capacity or less.

1.32 A trestle connects the fuel oil unloading pier to the shoreline. Extending north and south from the oil unloading pier are personnel walkways to the breasting and mooring dolphins. All of these structures are supported by piles anchored in the underlying rock stratum. The trestle piers, walkways and dolphins are constructed entirely of steel members. The supporting pile bents are widely spaced and provide a clearance beneath the trestle of approximately 15 feet at mean low water. Articulated metal arms are used for unloading vessels. A steam line to the unloading pier provides the heat necessary to maintain the fuel oil at approximately 100F to allow it to flow readily.

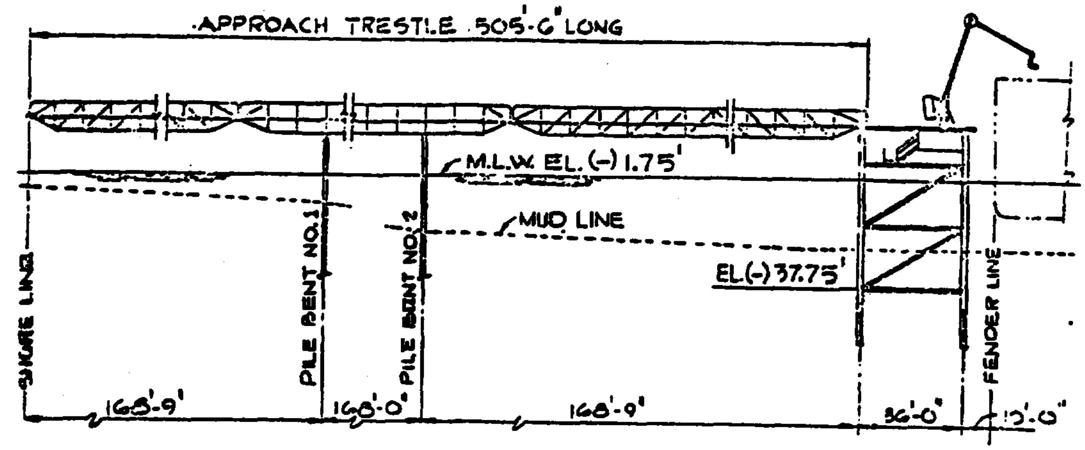
1.33 Further details of the fuel oil unloading terminal are given in Figures 1-5 and 1-6. As indicated, the dock structure is approximately 675 feet long and is oriented along a north-south line parallel to river flow, 500 feet from the west bank of the Hudson



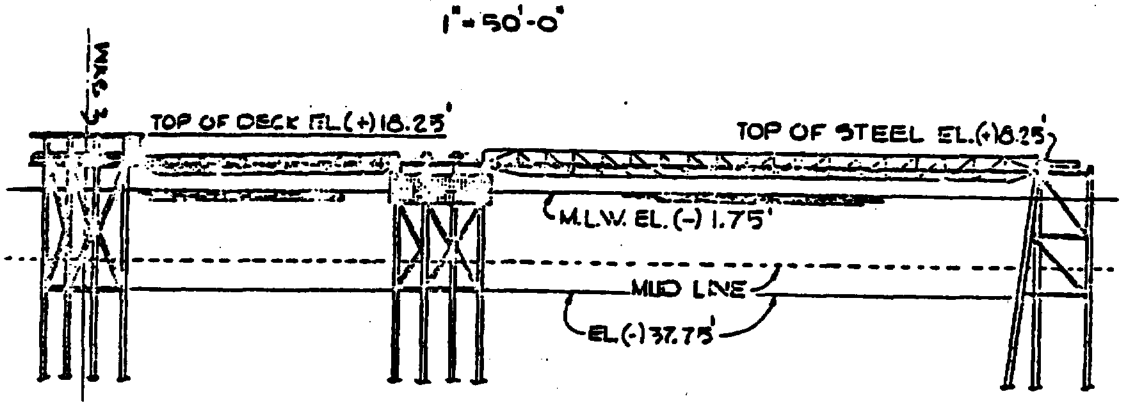
Source: Application to the District by Orange and Rockland.

FIGURE 1-5

FUEL OIL UNLOADING PIER-PLAN



SIDE ELEVATION
1" = 50'-0"



FRONT ELEVATION
1" = 50'-0"

Source: Application to the District by Orange and Rockland.

FIGURE 1-6

FUEL OIL UNLOADING PIER-ELEVATIONS

River. The transfer pier is centered at about latitude 41°12' North, longitude 73°57' West (New Yrok State coordinates 438710N and 603734E).

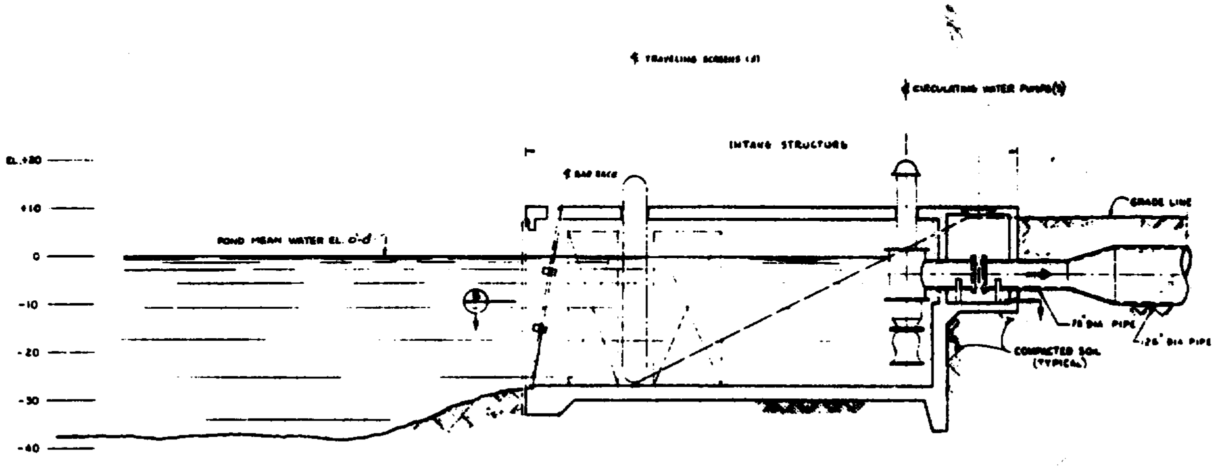
Intake Structure

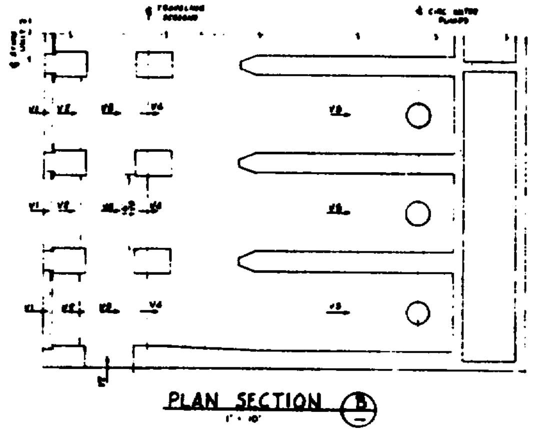
1.34 The cooling water intake structure is located on the northwest shore of Bowline Pond, directly across the pond from the inlet channel to the Hudson River. The major components of the intake system are the intake ports, common plenum, traveling screens, pump bays and circulating water pumps.

1.35 Pertinent engineering details of the intake structure are given in Figure 1-7. As indicated in the schematic, each of the six circulating pumps is housed in a separate bay. A common plenum is provided across the entire width of the structure to allow water from any intake port to enter any pump bay. Water enters the structure through a total of eight ports, six across the face of the structure and one on each side. The water first passes through the bar racks located behind the intake ports. Large fish and debris are prevented from entering the structure by 1/2 x 3-inch vertical bars with a 3-inch separation between bars.

1.36 Traveling screens are located approximately 16 feet behind the bar racks. The screens are of standard design adopted widely throughout the utility industry and consist of screen panels or "baskets" attached to an endless chain belt that revolves between two sprockets in a vertical plane. The screen mesh or size of the openings is three-eights inch square. While the circulating water pumps are in operation, the traveling screens are moved upward periodically and impinged fish and debris are lifted above the main floor of the intake building into a cleaning chamber. Water drawn from the pond is sprayed onto the screens through a row of nozzles. Two spray systems, a high and a low pressure system, operate at a pressure of 60 and 20 pounds per square inch, respectively. Waste waters from the backwash operation are sluiced to a tank with an outlet channel to Bowline Pond. The collection and return system provides an opportunity for fish that survive impingement and backwash to return to Bowline Pond.

1.37 Operating experience has shown that the frequency at which the screens must be moved and backwashed varies throughout the year. During periods of low debris loading of the river and low fish impingement, the screens are moved once every four hours. At other times, the screens run continuously. A mechanism drives the screens automatically on a signal of excessive water level differences across the face of the screen. The operation can also be controlled manually.





Source: Orange and Rockland, March 1971.

FIGURE 1-7

DETAILS OF THE COOLING WATER INTAKE STRUCTURE

1.38 Flow velocities at various points in the intake structure have been computed on the basis of estimated flow rates and cross sectional areas. The points are identified as V1 through V5 in Figure 1-7, and flow velocities under a number of conditions are given in Table 1-1. Values of velocity are given for mean water, mean low water and low low water elevations in Bowline Pond. Under normal conditions of full power operation (both units operating and 2 pumps running per generating unit), the approach velocity to the bar rack varies between 0.45 and 0.53 feet per second, depending on the water level in the pond. The corresponding values through the bar racks are 0.59 and 0.66 feet per second. The approach velocity to the screens varies between 0.54 and 0.64 feet per second and the velocity through the screens between 1.06 and 1.25 feet per second.

1.39 Water enters Bowline Pond from the Hudson River through an inlet channel that has been widened and deepened to augment flow into and out of the pond. Estimates of the flow velocities induced in the channel by the withdrawal of cooling water from the pond are given in Table 1-2. The velocities apply when both units are operating under conditions of mean water, mean low water and low low water elevations. With two pumps running per unit and a total withdrawal of 632,000 gallons per minute from Bowline Pond, velocities ranging between 0.44 and 0.60 feet per second are induced at the inlet; the range corresponds to extremes in water elevation. Under conditions of low low water and all 6 pumps operating, the induced velocity would reach a maximum of 0.74 feet per second.

1.40 The net velocity at the Pond inlet is the resultant of the velocity induced by the withdrawal of water and the flow velocity associated with tidal action. The mean tidal range of the Hudson River in the vicinity of Bowline Point is 2.9 feet (U.S. Department of Commerce, 1972), and the maximum flow velocity in the inlet channel corresponding to this tidal range is estimated to be 0.2 feet per second (Orange and Rockland, March 1971). Maximum flow occurs midway between the times of ebb slack and flood slack, with flow directed into the pond during flood tide and out of the pond during ebb tide. Accordingly, a value of 0.2 feet per second should be, respectively, added to and subtracted from the values given in Table 1-2 to obtain the net velocity in the channel during periods of inflow and outflow.

Discharge Diffusers

1.41 Discharge pipes from the condenser extend approximately 1,000 feeet due east into the Hudson River and terminate in two diffusers mounted at right angles to the pipes. The diffusers roughly parallel the fuel oil unloading dock and are slightly to the north and shoreward of the facility.

TABLE 1-1

FLOW VELOCITIES IN THE INTAKE STRUCTURE

WATER ELEVATIONS(1)	PUMPS OPERATING AND FLOW IN GALLONS PER MINUTE PER UNIT(2)	FLOW VELOCITIES IN FEET PER SECOND(3)				
		V1	V2	V3	V4	V5
Mean Water,	3 - 384,000	0.55	0.72	0.66	1.29	0.65
Elevation 0.00	2 - 316,000	0.45	0.59	0.54	1.06	0.79
	1 - 185,000	0.27	0.35	0.34	0.67	0.93
	2 - 257,000 Throttled Condition	0.37	0.48	0.44	0.86	0.64
Mean Low Water,	3 - 384,000	0.59	0.77	0.70	1.38	0.69
Elevation - 1.75	2 - 316,000	0.48	0.63	0.58	1.13	0.85
	1 - 185,000	0.29	0.37	0.36	0.72	1.00
	2 - 257,000 Throttled Condition	0.39	0.51	0.47	0.92	0.69
Low Low Water,	3 - 384,000	0.65	0.81	0.77	1.53	0.76
Elevation - 4.00	2 - 316,000	0.53	0.66	0.64	1.25	0.93
	1 - 185,000	0.31	0.34	0.40	0.79	1.10
	2 - 257,000 Throttled Condition	0.43	0.54	0.52	1.02	0.76

Source: Orange and Rockland, March 1971.

(1)Elevations refer to water level in Bowline Pond; see Figure 1-7.

(2)Velocity values apply when both power units are in operation; the values would be less than those indicated when only one of the units is in operation.

(3)The points at which the velocity values apply are identified in Figure 1-7 and are as follows:

V1 - average approach velocities to the bar racks
V2 - velocity through the bar racks
V3 - approach velocity to the screens
V4 - velocity through the screens
V5 - approach velocity to the pumps

TABLE 1-2

FLOW VELOCITIES IN THE BOWLINE POINT INLET CHANNEL

WATER ELEVATIONS(1)	PUMPS OPERATING PER UNIT AND TOTAL FLOW(2) IN GALLONS PER MINUTE	FLOW VELOCITY(2) IN FEET PER SECOND
Mean Water,	3 - 768,000	0.54
Elevation 0.00	2 - 632,000	0.44
	1 - 370,000	0.26
	2 - 514,000 Throttled condition	0.36
Mean Low Water,	3 - 768,000	0.61
Elevation - 1.75	2 - 632,000	0.50
	1 - 370,000	0.29
	2 - 514,000 Throttled condition	0.41
Low Low Water,	3 - 768,000	0.74
Elevation - 4.00	2 - 632,000	0.60
	1 - 370,000	0.35
	2 - 514,000 Throttled condition	0.49

Source: Orange and Rockland, March 1971.

(1)Elevations refer to water level in Bowline Pond; see Figure 1-7.

(2)Total flows and velocities apply when both units are operating; values are approximately one-half those indicated when only one unit is operating.

1.42 Each diffuser consists of a 220-foot section of 126-inch diameter pipe with eight discharge nozzles. The nozzles are 3 feet in diameter, spaced 25 feet on centers and inclined 5 degrees from the horizontal to reduce scouring of the river bottom. Heated water leaves the nozzles with a velocity of approximately 15 feet per second. The jets induce turbulence and mixing with ambient waters, producing a rapid reduction in the temperature of the effluent stream. Details of the dischage piping and diffusers are given in Figure 1-8.

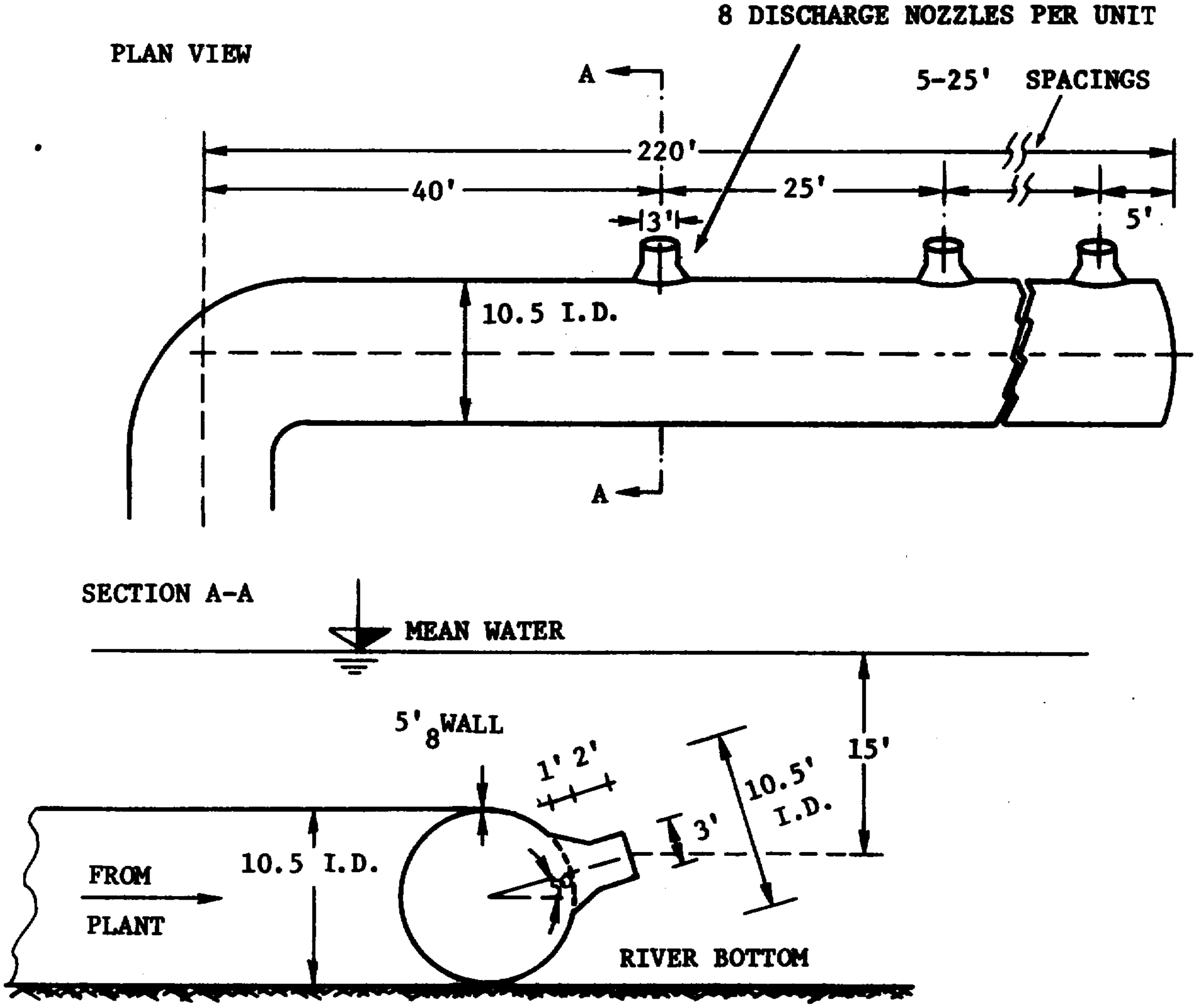
Recreational Facility

1.43 Orange and Rockland and Con Edison deeded to the town of Haverstraw 10.8 acres of land as the Bowline Point site for the development of a public recreational facility. The same companies contributed a total of $750,000 towards construction costs of the amenities and the town expended an additional $300,000 (Rotella, 1976). The facility, which is operated by the Town of Haverstraw, now includes a swimming pool and dressing rooms, picnic areas, basketball and tennis courts, and a pavilion. The park has been open to the public since late summer of 1976. An admission fee is charged for each visit to the center; daily and seasonal rates are available. Access by road to the facility is unrestricted.

Site Preparation

1.44 Site preparation at Bowline Point prior to construction of the power plant entailed the removal of existing garbage, draining and filling of certain portions of the site, pest and rodent control measures, the relocation of a portion of Minisceongo Creek, and dredging of the inlet to Bowline Point. Parts of the site had been used as a dump for discarded automobiles, household appliances and other garbage and for casual trash disposal (Orange and Rockland, March 1971). The garbage fill, up to 10 feet in depth in certain sections, was removed from all areas now occupied by major structures and replaced by clean fill dirt. In other areas of the site the garbage was covered with clean fill and compacted.

1.45 Low lying portions of the property were occupied by stagnant ponds and poorly drained areas. A drainage system consisting of surface drainage channels and underground storm sewers was constructed to provide drainage to Minesceongo Creek or Bowline Pond. Where adequate drainage existed, growths of scrub brush and larger trees had become established. Programs of vegetation clearing and rodent and insect extermination were carried out concurrently with excavation and site grading (Orange and Rockland, March 1971).



Source: Orange and Rockland, March 1971

FIGURE 1-8

DETAILS OF DISCHARGE DIFFUSERS AT THE BOWLINE POINT GENERATING STATION

1.46 The portion of Minisceongo Creek to the east of the present power plant building traversed a low lying part of the site, and the creek channel became ill defined in the area. To prevent flooding and improve drainage, a diversion channel was cut between the existing creek bed and the Hudson River. The channel is subject to tidal inflow; excess water flows northward off the property along the remainder of the original water course and ultimately is discharged to the river.

1.47 The existing inlet channel between Bowline Pond and the Hudson River was shallow and permitted limited tidal flow between the pond and the Hudson River. The channel was dredged to a depth of 16 feet and a top width of 219 feet to increase tidal flow into and out of the pond. Approximately 49,000 cubic yards of material were removed in dredging the inlet channel; the dredged material was used for onland fill on the property. An additional 51,000 cubic yards of material were dredged in laying the subaqueous cooling water lines and discharge diffusers. The material was used to fill in an existing pond to the north of the power plant site.

1.48 The primary access road to the plant extends from an intersection at Samsondale Avenue immediately north of the bridge over Miniscenongo Creek to the plant parking lot. Intraplant roads, closed to public traffic, extend northward from the parking lot, providing access around the power plant building, shop and warehouse. Immediately to the west of the parking lot, a branch of the access road extends southeast to the intake structure and then along the north shore of Bowline Point to the recreational facility and marine terminal.

1.49 The intersection at Samsondale Avenue was planned to minimize interference with local traffic and accomodate the anticipated high volume of traffic related to the use of the recreational facility during summer months. Samsondale Avenue has been widened to allow through traffic to bypass vehicles turning onto the access road. Additionally, vehicles from the plant can enter Samsondale Avenue safely and without undue delay. The intersection was designed to obviate traffic lights.

1.50 A through girder, clear span bridge provides a crossing over Minisceongo Creek. The bridge consists of two 15-foot traffic lanes and walkways on either side. The bridge is designed to carry a heavy crane which may be required once in several years for maintenance work at the intake structure and, therefore, provides ample capacity for the heaviest automobile and truck traffic. The clear span across the creek ensures that the bridge will be safe during periods of heavy runoffs.

1.51 McKenzie Avenue in the Village of Haverstraw (the extension of Warren Avenue shown in Figure 1-1) was extended to intersect the site access road near the plant intake structure, providing an alternative route to the recreational facility. Rerouting of the original McKenzie Avenue required the acquisition of the right-of-way presently following the lines shown in Figure 1-2.

1.52 Additional access to the site during construction was provided by an extension of Railroad Avenue. The road has since been closed to plant traffic, except for occasional maintenance and delivery use. A railroad spur leading from the Conrail Railroad in the Town of Haverstraw was constructed on a right-of-way purchased by Orange and Rockland. This spur was used mainly during construction of the plant; train passage is currently infrequent and limited to occasional delivery.

Transmission Lines

1.53 Connecting the Bowline Point station to existing power distribution networks serving the Orange and Rockland and New York Power Pool systems required the construction of approximately 3.4 miles of underground 345-kilovolt transmission line circuits. The transmission lines from the plant are routed to Orange and Rockland's West Haverstraw substation located 1.2 miles west of Samsondale Avenue. Underground construction was selected to eliminate the visual impact of overhead transmission lines in residential areas.

Current Project Status

1.54 Construction of the first unit at the Bowline Point Generating Station began in the Spring of 1969. Unit No. 1 entered limited commercial service on 8 September 1972 and full commercial service on 21 October 1972. Unit No. 2 entered commercial service on 1 May 1974.

1.55 All site preparation, landscaping and other site closeout work is complete. Construction work related to the generating units is complete. The marine terminal has been ready to receive oil since 5 April 1972. Dredging operations are complete. The recreational facility, first opened to the public late in the 1976 season, is now operational.

1.56 Table 1-3 lists the applications filed by Orange and Rockland and the major approvals that have been secured to date from various governmental entities, in connection with the Bowline Point Generating Station are listed in Table 1-3.

TABLE 1-3

APPLICATIONS AND APPROVALS RELATED TO THE BOWLINE POINT GENERATING STATION

AGENCY	PERMIT/APPROVAL	DATE OF ISSUANCE	REFERENCE/STATUS
U.S. Environmental Protection Agency, Region II	National Pollutant Discharge Elimination System Permit	31 Mar 75	Permit No. NY0008010 Exp. 30 Mar 1980
U.S. Army, Corps of Engineers, New York District	Dredging of inlet channel, installing of discharge piping and construction of a mooring facility (Section 10 Permit)	12 Jul 71	Permit No. 8304
U.S. Department of Transportation, Federal Aviation Administration	Permit to construct plant and stack	5 May 71	71-EA-203-OE
New York State Department of Environmental Conservation, formerly Department of Health	Construction permit for circulating water system	26 Oct 71	Form San. 2
	Operating permit for circulating water system	14 Nov 74	(NY0008010) 2SDOXW2000897
	Fuel oil facility rain water discharge	25 Apr 72	Permit dated 25 Apr 72
	Atmospheric discharge --permit to construct main boiler	7 Apr 71	Application No. C-700024
	Atmospheric discharge --permit to operate main boiler	7 Apr 71	Permit No. C-700024, Pending
	Atmospheric discharge --permit to construct auxiliary boiler	16 Aug 71	Letter advising no permit required (Letter No. W44-C71-0040)
	Atmospheric discharge --permit to construct auxiliary boiler	16 Aug 71	Letter advising no permit required (Letter No. W44-C71-0040

TABLE 1-3 (continued)

APPLICATIONS AND APPROVALS RELATED TO THE BOWLINE POINT GENERATING STATION

AGENCY	PERMIT/APPROVAL	DATE OF ISSUANCE	REFERENCE/STATUS
New York State Department of Environmental Conservation, formerly Water Resources Commission	Permit to construct intake structure and to dredge ponds	22 Jun 71	Intake Application No. 8-5-70 8-7-71*
		3 Nov 71	Discharge Application No. 8-5-70
	Permit to construct fuel oil unloading pier	26 Jun 70	Application No. 8-4-70
	Permit to install culverts in Minisceongo Creek for railroad siding	5 Aug 70	8-47-70
	Permit temporarily to relocate creek into Bowline Pond, construct bridge and improve creek channel	17 Sep 70	8-76-70
	Permit tp place fill in Bowline Pond	21 Sep 70	8-77-70
	Permit to place fill in pond north of Bowline Point	23 Dec 70	8-94-70
New York Public Service Commission	Approval of railroad crossings at Grassy Point Road and Gagan Road	28 Aug 70	Petition Case No. 25778
New York Commissioner of General Services	Purchase of underwater property for circulating water discharge and fuel oil unloading pier	27 Jan 72	Letter dated 27 Jan 72 filed under Liber 904 Pg. 794
Hudson River Valley Commission	Formal project review and approval	14 Apr 71	Letter dated 14 Apr 71
Rockland County Drainage Agency	Permit to install culverts in Minisceongo Creek for railroad siding	N. A.	N. A.

*No. 8-7-71 permits Orange and Rockland to remove more material.

TABLE 1-3 (concluded)

APPLICATIONS AND APPROVALS RELATED TO THE BOWLINE POINT GENERATING STATION

AGENY	PERMIT/APPROVAL	DATE OF ISSUANCE	REFERENCE/STATUS
Rockland County Highway Department	Approval of railroad crossing at Grassy Point Road	13 Aug 70	Letter
	Permit to install bridge over Minisceongo Creek for access to road to recreation area	8 Oct 70	Letter
Town of Haverstraw	Building permit, warehouse and shop	16 Sep 69	Permit No. 958.959
	Building permit; main plant, service building, switchyard and miscellaneous structures	5 Aug 71	Permit No. 661
	Approval of railroad crossing at Gagan Road	12 Aug 70	Letter
Village of Haverstraw	Building permit, circulating water intake structure	9 Mar 71	Permit No. 191
	Building permit, oil tanks and pier	9 Mar 71	Permit No. 192
Village of West Haverstraw	Approval of sanitary and waste disposal of sewage treatment plant	18 Mar 70	Letter

Project Review

1.57 Construction plans related to Bowline Point Unit 1 were reviewed by the Hudson River Valley Commission in 1971. In accordance with the provisions of the New York State legislative act that established the Commission in the mid-1960s, the Commission was required to review all proposed construction projects on the Hudson River, devoting attention to the visual impacts associated with each project, the impact on surrounding communities, the ecology of the river and broader environmental issues concerning the Hudson River basin.

Waterborne Discharges

1.58 The discharge of liquid effluents from the plant to the Hudson River and Minisceongo Creek is currently authorized by a National Pollutant Discharge Elimination System permit issued on 31 March 1975 by the U.S. Environmental Protection Agency in accordance with the provisions of the Federal Water Pollution Control Act Amendments of 1972 (33 U.S.C. 1251-1375).* Among other restrictions, the permit imposes limitations on the following: thermal discharges to the Hudson River (5.8 billion BTU per hour maximum heat rejection, 23oF maximum temperature increase 102F maximum temperature of discharge). The pH (range of 6.0 to 9.0 unless pH of the intake falls outside this range; then the pH of the discharge may not vary by more than 0.2 pH units from the pH of the intake) and content of free available chlorine in the discharge (0.2 milligrams per liter). Daily average velocity at the traveling screens (0.77 feet per second). Oil and grease content of discharges at Minisceongo Creek (15 milligrams per liter average, 20 milligrams per liter maximum).

Bring up to date by reference to applicant for State SPDES permit + continuation of "expired" permit issued by EPA

1.59 In accordance with the conditions of the permit, Orange and Rockland is required to adhere to the following schedule related to the retrofitting of a closed cycle cooling system:

(1) The permittee is required to complete an engineering report and submit the report to the New York Department of Environmental Conservation in accordance with New York State requirements by 1 January 1977.

State whether this was completed

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*For the sake of consistency, reference to the Federal Water Pollution Control Act Amendment is maintained in the Final Environmental Statement although the 1972 Statute has been amended and renamed the Clean Water Act (PL95-217) on 28 December 1977.

Done on time

(2) The permittee is required to complete final plans and specifications for the cooling system and submit these to the New York Department of Environmental Conservation by 1 June 1977.

(3) The permittee is required to submit reports detailing progress toward completion of the facilities by 1 March 1978, 1 December 1978, 1 September 1979, and 1 June 1980.

note this was stayed.

(4) The permittee is required to complete construction of the facilities by 1 April 1981.

(5) The permittee is required to attain operational levels of closed-cycle cooling by 1 July 1981.

1.60 On 30 July 1974, Orange and Rockland requested the U.S. Environmental Protection Agency, Region II to waive the requirement for closed cycle cooling, in accordance with the provisions of Section 316(a) of the Federal Water Pollution Control Act Amendments of 1972. Orange and Rockland prepared and submitted a demonstration document* in support of this request.

True?

1.61 As presently set forth, the terms of the National Pollutant Discharge Elimination System permit effectively constitute a denial of a waiver under Section 316(a) of the Federal Water Pollution Control Act Amendments. Concern over the continued operation of the Bowline Point Station with open cycle cooling centers on the damage to aquatic organism caused by the withdrawal of water from the Hudson River rather than the effects of the thermal discharge (Section 4). Accordingly, the requirement to install a closed cycle cooling system stems principally from Section 316(b) which provides that effluent limitations and standards of performance established in accordance with the statute "shall require that the location, design, construction and capacity of cooling water intake structures reflect the best technology available for minimizing environmental impact." The Environmental Protection Agency regards the term "capacity" to be synonymous with "throughout" or "flow rate" in the context of Section 316(b) (U.S. Environmental Protection Agency, 1976; 40 CFR 402);

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*Before the United States of America, Environmental Protection Agency, Region II, Re: Demonstration by Orange and Rockland Utilities, Inc. That operation of the Bowline Generating Station at Haverstraw, New York, with the Existing Once-Through Circulating Water System for Condenser Cooling, Will Assure the Protection and Propagation of a Balanced, Indigenous Population of Shellfish, Fish and Wildlife in and on the Hudson River in the Vicinity of Haverstraw and Elsewhere, Dated at Spring Valley, New York, 30 July 1974.

adding reason to consider closed cycle cooling as the "best available technology economically achievable" with respect to the rejection of waste heat from steam-electric power plants. With closed cycle cooling, a power plant's requirement for water is reduced typically to 2 or 3 percent of the requirement associated with open cycle cooling, leading in principle to a reduction in the number of aquatic organisms destroyed or injured by the operation of the power plant. Orange and Rockland is contesting the requirement for closed cycle cooling at the Bowline Point Station in an adjudicatory hearing before the Environmental Protection Agency (Appendix B). Other utility companies operating power plants sited on the Hudson River and subject to similar requirements to backfit closed cycle cooling systems are parties in the same proceeding, currently in progress.

not true

Airborne Discharges

1.62 Permits to construct the main station boilers have been issued by the New York State Department of Environmental Conservation but certificates to operate the main boilers have been withheld pending the resolution of a question of potential violations of certain New York State regulations related to ambient air quality.

Time element is inconsistent with present time

1.63 A preliminary analysis carried out prior to construction of the station indicated that both hourly and 24-hour average limitations on ambient sulfur dioxide concentrations would be exceeded on the ridge line and peak areas to the southwest of the plant under conditions of strong northeasterly winds (Orange and Rockland, 1971). No problems with respect to particulates or nitrogen oxides were anticipated at the time.

1.64 More extensive analyses (Orange and Rockland, 1972, 1973a) confirmed the findings of the earlier study and pointed to the need for 650-foot stack(s) to circumvent potential problems in meeting ambient air quality standards relating to sulfur dioxide. Orange and Rockland opted to retain the 287.5-foot stacks and implemented an observation program to monitor pertinent meteorological and air quality factors in the vicinity of the site. Plans were drawn up to burn (low sulfur) natural gas during periods when ambient concentrations of sulfur dioxide would be expected to exceed regulatory standards. The company has been unable to secure an adequate supply of gas to implement this strategy.

true ?

1.65 Orange and Rockland is currently under an order on consent from the New York State Department of Environmental Conservation to erect a 650-foot stack or to continue field measurements, carry out plume trajectory studies and report the findings of investigations to the Department of Environmental Conservation on a yearly basis until the matter is resolved. The critical area with respect to potential violations has been identified as the Hightor ridge to the southwest of the plant. A monitoring network (three monitoring stations) has been established where the concentrations of sulfur dioxide are expected to be highest during periods of adverse wind conditions.

1.66 Orange and Rockland has submitted two annual reports to the Department of Environmental Conservation covering the period June 1974 through May 1976. No instances of ambient air quality violations have been reported to date and a certificate to operate the main boilers has been issued by the New York State Department of Environmental Conservation. Meteorological and air quality monitoring are to continue as a condition of operation.

OTHER MAJOR PROJECTS ON THE LOWER HUDSON RIVER

1.67 Pertinent characteristics of generating stations on the lower Hudson River are summarized in Table 1-4, and the locations of these stations are shown in Figure 1-9. The existing seven stations represent a total generating capability of the order of 6,000 megawatts of which approximately 2,000 megawatts is nuclear-fueled capability, 2,400 megawatts is oil-fueled capability, and 1,400 megawatts is coal-fueled capability that has been converted to burn oil. In accordance with the provisions of Section 2 of the Energy Supply and Environmental Coordination Act of 1974 (P.L. 93-319 as amended by P.L. 94-163), the U.S. Federal Energy Administration has issued an order prohibiting the burning of petroleum products at the plants with the capability of burning coal.

1.68 All the existing stations currently operate with open-cycle or once-through condenser cooling systems. The U.S. Environmental Protection Agency has imposed the requirement that closed-cycle cooling systems be installed at the Bowline Point and Roseton Generating Stations and at Units 2 and 3 of the Indian Point station. Conditions to the National Pollutant Discharge Elimination System permits authorizing the discharge of liquid effluents from these stations stipulate that closed-cycle cooling systems be installed and fully operational at various dates in 1981 and 1982. This requirement, in each instance, is being contested and adjudicatory hearings on these matters are presently being held before the U.S. Environmental Protection Agency. No requirements to install closed cycle cooling system at the other stations on the Hudson River Estuary are presently being imposed by the U.S. Environmental Protection Agency.

TABLE 1-4

PERTINENT CHARACTERISTICS OF EXISTING GENERATING STATIONS ON THE LOWER HUDSON RIVER

STATION (COMPANY)	LOCATION (RIVER MILE)		CAPACITY IN MEGAWATTS[1]		YEAR OF INITIAL OPERATION	PRIMARY FUEL	CONDENSER COOLING
			CURRENT	ULTIMATE			
Albany (Niagara Mohawk)	Bethlemen, 142		400	400	1952	Oil/Coal	Open Cycle
Danskammer (Central Hudson)	Newburgh, 66.3		500	500	1951	Oil/Coal	Open Cycle
Roseton[2] (Central Hudson, Con Edison, Niagara Mohawk)	Newburgh, 65.8		1200	1200	1974	Oil	Closed Cycle Required by 7/1/81
Indian Point[3] (Con Edison, Power Authority	Buchanan, 43	Unit 1	0	262	1962	(4)	Open Cycle
		Unit 2	864	1042	1973	Nuclear	Closed Cycle Required by 5/1/82
		Unit 3	965	1033	1976	Nuclear	Closed Cycle Required by 9/15/82
Lovett (Orange and Rockland)	Tompkins Cove, 41.5		500	(+400)	1949	Oil/Coal	Open Cycle
Bowline Point[5] (Oraange and Rockland, Con Edison)	Haverstraw, 37.5		1200	(+400 to 600)	1972	Oil	Closed Cycle Required by 7/1/81
59th Street (Con Edison)	Manhattan, 5		82	82	1918	Oil	Open Cycle

[1] Exclude gas turbine capability

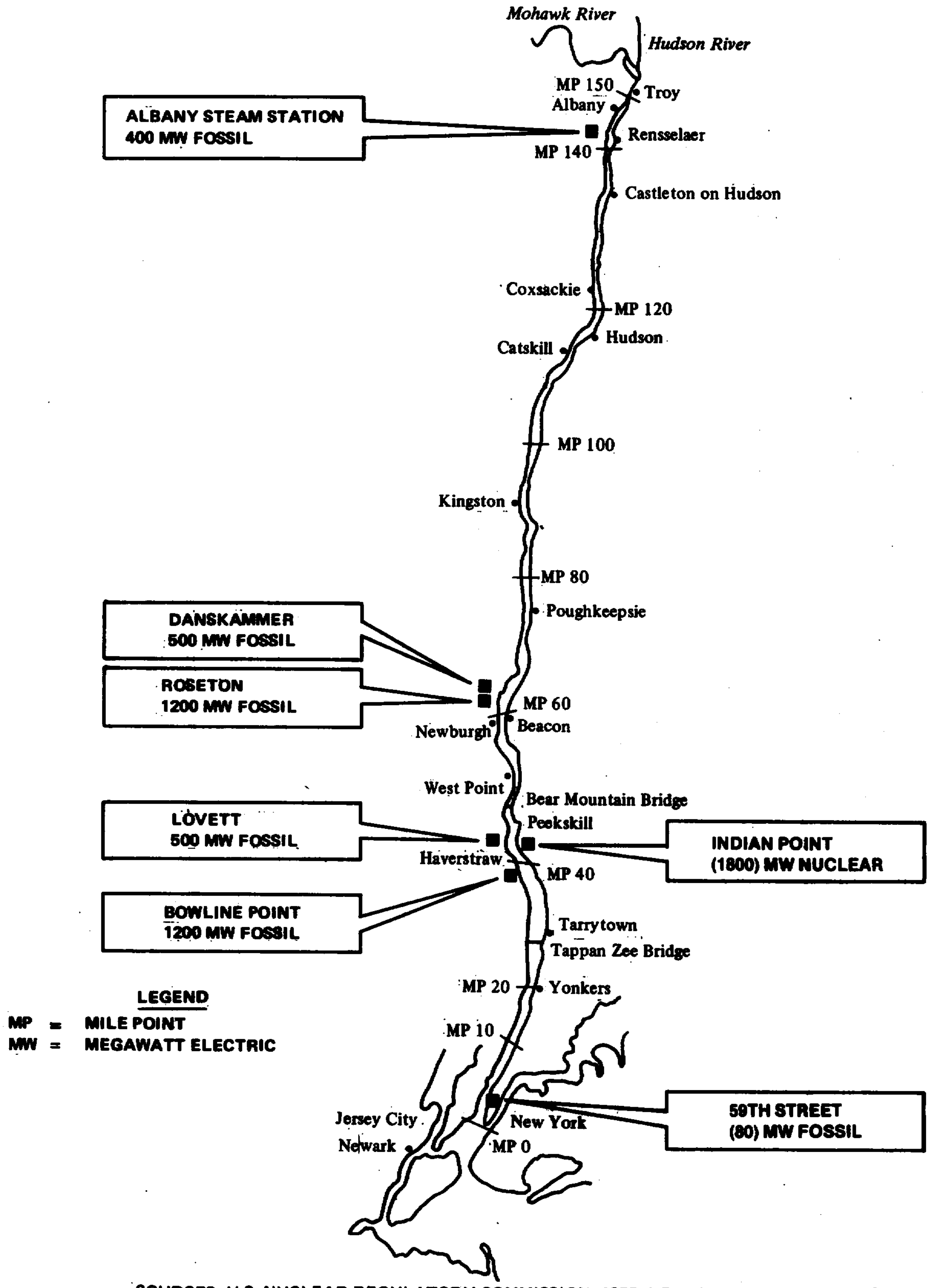
[2] Central Hudson's share of capability is 360 megawatts; Con Edison's share is 480 megawatts; Niagara Mohawks's share is 360 megawatts.

[3] Ownership of Unit 3 was transferred from Con Edison to the Power Authority of the State of New York on 31 December 1975.

[4] Indiana Point Unit No. 1 is a nuclear unit with oil-fired superheat; it is considered by Con Edison to be inoperable pending the installation of an emergency core cooling system.

[5] Orange and Rockland's share of capability is 401 megawatts; Con Edison's share is 801 megawatts.

Source: New York Power Pool, 1979.



SOURCES: U.S. NUCLEAR REGULATORY COMMISSION, 1975; NEW YORK POWER POOL, 1976.

FIGURE 1-9
EXISTING POWER GENERATING STATIONS
ON THE HUDSON RIVER ESTUARY

Albany Steam Station

1.69 The Albany site, owned by Niagara Mohawk, currently accommodates four oil-fueled units, each of 100-megawatt capacity, which has been and in operation since 1952. The approximate ultimate capacity that the site can support is estimated to be 800 megawatts (New York Power Pool, 1976).

1.70 No additions to the site are currently proposed or contemplated (New York Power Pool, 1976). A major constraint on future expansion of the plant is considered to be the limitation of the river as a source of cooling water. The visibility of natural draft cooling towers and their potential to induce fogging are additional factors that would inhibit expansion of the Albany site (New York Power Pool, 1976).

update to 1980

Danskammer

1.71 The Danskammer Point Generating Station comprises four oil-fired units with an aggregate generating capacity of 472 megawatts. The oldest units have been in operation since 1951. There are no plans at present to uprate the station or to install additional generating capacity at the Danskammer site.

date this?

Roseton

1.72 The Roseton site occupies 133 acres in the Village of Roseton, Town of Newburgh, Orange County, New York. The station comprises two fossil-fueled units with a combined net capability of 1,200 megawatts. There are no plans at present to install additional generating capacity at the Roseton site.

Indian Point

1.73 The Indian Point Nuclear Generating Station is located in the Village of Buchanan, Westchester County on a 239-acre site on the east bank of the Hudson River at Mile Point 43. The generating facilities occupy 35 acres of the site (U.S.Nuclear Regulatory Commission, 1975) and include Indian Point Units 1, 2, and 3. Units 1 and 2 are owned by Con Edison. Ownership of Unit 3 was transferred from Con Edison to the Power Authority of the State of New York on 31 December 1975.

1.74 Unit 1, supplied by the Babcock and Wilcox Company, is of unique design in that it features a pressurized water reactor with oil-fired superheating of the main steam. A construction permit for the unit was issued by the Atomic Energy Commission in 1956 and the unit was first put into service on 30 September 1962, under an operating license issued earlier in that year. The unit has been shut down since 31 October 1974 for the purpose of installing an emergency core cooling system (U.S. Nuclear Regulatory Commission, 1975). The date on which the unit will resume service is undetermined. Accordingly, the New York Power Pool generation plan (1976-1991) excludes any contribution from Unit 1 (New York Power Pool, 1976).

has been decommissioned

1.75 Units 2 and 3 incorporate pressurized water reactors supplied by the Westinghouse Corporation. Construction permits for Units 2 and 3 were issued by the Atomic Energy Commission, in 1966 and 1969 respectively. A license to operate Unit 2 at 100 percent steady-state power was issued on 28 September 1973. The Nuclear Regulatory Commission issued the final environmental statement related to the operation of Unit 3 (operating license) in February 1975 (U.S. Nuclear Regulatory Commission, 1975) when commercial operation was anticipated in the latter half of 1975. Commercial operation of Unit 3 began in August 1976.

date →

date

1.76 The generating capacities of the Indian Point units, excluding possible deratings as a result of installing closed-cycle cooling systems, are as follows:

UNIT	CURRENT (1979) CAPACITY (megawatts)	POTENTIAL UPRATINGS (megawatts)	ULTIMATE CAPACITY (megawatts)
1	0	--	265
2	864 true?	169 being considered now	1033
3	965	68	1033

Source: U.S. Nuclear Regulatory Commissions, 1975; New York Power Pool, 1979.

Lovett Station

1.77 The existing Lovett Station is owned by Orange and Rockland and located in Tomkins Cove, Rockland County at Mile Point 41.5 on the west bank of the Hudson River. The station comprises five oil fueled units, with an aggregate generating capability of 506 megawatts. Commercial operations at the Lovett Station began in 1949.

date

1.78 There are currently no plans (through 1991) to uprate or retire any of the generating units. Initial studies indicate that a further 400 megawatt oil-fueled unit could be supported by the existing site with some additional acquisition of property (New York Power Pool, 1976). The addition would entail the need to upgrade or expand the existing transmission facilities and some landfill work in the Hudson River in the northern portion of the site.

retire ?

Bowline Point Generating Station

1.79 No detailed evaluation of the total generating capability that could be installed at the present Bowline Point site has been made to date. Initial studies indicate that the site could support an additional 400 to 600 megawatts of capacity (New York Power Pool, 1976). The most logical addition would appear to be a single coal/oil fueled unit that would raise the present station capacity of 1,200 megawatts to an ultimate capacity of 1,600 to 1,800 megawatts. The addition would entail relatively minor upgrading or expansion of transmission, transportation, and fuel handling facilities. There are, at present, no plans to increase the generating capability of the Bowline Point Generating Station.

date

59th Street Power Plant

1.80 The 59th Street plant is a common header station owned in fee by Con Edison and located in Manhattan at Mile Point 5 on the east bank of the Hudson River. In addition to the conventional thermal units, the plant houses two kerosene-fired gas turbine units with a combined sustained capacity of 28 megawatts in summer and 36 megawatts in winter, and a combined maximum capacity of 34 megawatts in summer and 40 megawatts in winter.

Future Power Plant Developments

1.81 Substantive changes in the long term generation plans of the New York Power Pool have been made in the past few years. Included in these changes are the deferral or cancellation of a number of power plant projects on the Hudson River estuary at one time proposed or considered as likely developments. According to the New York Power Pool's most recent plan covering the period 1979 through 1994, there are no major expansions of existing facilities on the Hudson River or new construction scheduled within this period (New York Power Pool, 1979).

cite 1990 report

1.82 Upratings of power plants on the Hudson River estuary are limited to an increase of 9 megawatts in the capability of Indian Point Unit 2 to be effected in 1979 (New York Power Pool, 1979). Provisions in the original design of both units at Indian Point would

Never realized -

allow the capability of each unit to be raised ultimately to levels discussed previously. These upratings would entail no major site preparation or installation of new equipment.

Possible Future Project

1.83 All of the future projects on the Hudson River estuary at one time included in the New York Power Pool's generation plans are now considered as indefinite possibilities that could materialize in the 1990's or beyond. These projects consist of the Cornwall pumped storage hydroelectric project, the Greene County Nuclear Power Plant, the NYSE&G Nuclear project and the Mid-Hudson West project.

1.84 Cornwall. Originally announced by Con Edison in 1962, the Cornwell pumped storage hydroelectric project comprises an upper reservoir around Whitehorse Mountain to the south-southwest of Storm King Mountain and pumping/generating facilities on the Hudson River at Cornwall Landing. The Federal Power Commission approved the project in 1965 but, following an appeal by several conservation groups allied as the Scenic Hudson Preservation Conference, was ordered by the U.S. Court of Appeals to review its approval of the project, giving due consideration to the effects the project might have on the environment.

1.85 Public hearings on the projects have been held at various times. If the Federal Power Commission ultimately authorizes the project, an estimated maximum capacity of 3000 megawatts could be installed at the site (New York Power Pool, 1976).

1.86 Green County. Plans to construct the Green County Nuclear Power Plant (U.S. Nuclear Regulatory Commission, 1976) near the Hamlet of Cemeton have been cancelled by the Power Authority of the State of New York (Nucleonics Week, 12 April 1979). As an alternative to the proposed 1200-megawatts nuclear power plant, the Power Authority intends to seek the necessary approvals to construct coal-fired facilities in Green County or elsewhere in the state. It is unknown at present whether the alternate capacity would be brought on line by late 1989, the date scheduled for the operation of the Green County Nuclear Power Plant according to the New York Power Pool's "energy strategy" plan (New York Power Pool, 1979).

canceled?

1.87 NYSE&G Nuclear. As currently projected, the NYSE&G Nuclear power plant proposed jointly by Long Island Lighting Company and New York State Electric and Gas Corporation would be located at New Haven, New York on Lake Ontario (New York Power Pool, 1979). Now designated the New Haven project, the power plant would comprise two nuclear units, each of 1,250 megawatts capacity, scheduled to be operational in 1992 and 1994.

deferred?

1.88 A site at Stuyvesant in Columbia County on the east bank of the Hudson River Estuary is being considered as an alternative to the New Haven site. Coal as an alternative to nuclear fuel is receiving consideration for both the New Haven and Stuyvesant sites.

1.89 Mid-Hudson West. An announcement related to a large generating complex, comprising five base load units scheduled to come into service between 1984 and 1991, was first made by Con Edison in 1973 (Nuclear Industry, 1973). Details concerning the type of units and site were not disclosed. The most likely location was described at the time as a site on the west bank of the Hudson River, north of Newburgh and behind the first row of hills along the shore. Con Edison was simultaneously evaluating alternative sites on both banks of the Hudson River north of the Poughkeepsie as well as sites on Lake Ontario and the St. Lawrence River.

1.90 Plans relating to the Mid-Hudson West project are presently indefinite. Consideration is being given to nuclear or coal fueled facilities, possibly to be located at the Red/Hook/Clermont site along the Columbia Dutchess county line on the east bank of the Hudson River Estuary.

no longer current

Siting Options

1.91 A number of sites on the Hudson River have been tentatively characterized as capable of meeting the technical requirements of large generating facilities and as acceptable in terms of current environmental standards. A survey* of candidate sites for the Greene County Nuclear Power Plant (U.S. Nuclear Regulatory Commission, 1976) identified nine potential alternatives,** most deemed suited as sites for fossil-fueled plants as well, on both banks of the Hudson River between Newburgh to the south and Hudson to the north.

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*The specific criteria used by the Power Authority of the State of New York in the evaluation of siting alternatives are the following: impact on air quality, impact on water quality; environmental compatibility of once-through cooling (including hydrothermal criteria and impact on aquatic ecology), environmental compatibility of closed cycle cooling (including space availability, fogging and icing effects, drift effects and height limitations of natural draft towers), visual and social impacts, present and future land use, population density, impacts on terrestrial ecology, meteorology and engineering feasibility.

**Closed-cycle cooling was found to be a prerequisite in all nine cases.

1.92 Initial findings indicated that among the sites, four would be less favorable than the others for various reasons, including distance to the source of water, potential foundation problems and the possibility of flooding. Further assessment of the five remaining sites--the Denning Point site within the City of Beacon, Dutchess County; the Lloyd site in the Town of Lloyd, Ulster County; the Cruger Island site in the Town of Red Hood, Dutchess County; the Cementon site in the Town of Catskill, Greene County; and the Athens-Leeds site in the Town of Athens, Greene County--established the relative advantages and disadvantages of each site and demonstrated that the Cementon and Athens-Leeds would be preferable. A final selection of the Cementon site was made on the basis of certain financial and socioeconomic factors.

1.93 The review of this selection by the U.S. Nuclear Regulatory Commission in 1976 reveals only small differences in the indices of merit assigned to each site, particularly the sites chosen in the latter stages of the screening process. With information now available, there are no indications that these sites would be rejected as potential candidates for future projects.

1.94 In addition to the above sites, the member companies of the New York Power Pool have some form of possessory interest in a number of other undeveloped (with respect to power generation facilities) sites. Several among these are on the Hudson River. Although there are no current plans to develop these sites on or before 1991 (New York Power Pool, 1976), their potential for development is considered briefly in the following sections.

true?

1.95 Verplanck. The Verplanck site occupies 142 acres in the Village of Buchanan and is owned by Con Edison. The site is in close proximity to the Indian Point generating facilities. Con Edison contemplates the installation of 800 megawatts of gas turbine capacity at some time in the future beyond 1991, if the company is unable to site the gas turbines closer to load centers and transmission facilities (New York Power Pool, 1976).

1.96 Since the Verplanck site is part of an industrial tract that presently includes the Indian Point Station, land use restrictions are not considered to be an impediment to the future development of the site. In accordance with Title 6, New York State Official Compilation of Codes, Rules and Regulations, Part 660, a Tidal Wetlands Moratorium Permit would have to be secured if the development of the site would entail a significant effect on the existing condition of any tidal wetland area.

1.97 Ward Manor. The Ward Manor site occupies 768 acres in the Town of Red Hook, Dutchess County, the site is owned by Central Hudson and includes Cruger Island, one time an island in the Hudson River but now a peninsula linked to the mainland by alluvial deposits (U.S. Nuclear Regulatory Commission, 1976).

1.98 Although no determination has been made to date of the maximum generating capacity that could be supported by the site and Central Hudson has no plans to develop the site, the general area has been identified as a potential candidate site for the Green County Nuclear Plant. By a zoning ordinance adopted in July 1974, the Town of Red Hook has designated the area for residential development on minimum 5-acre plots. Construction of generating facilities at this site, therefore, would require rezoning of the portions of the site required for the facilities (New York Power Pool, 1976).

1.99 Terry Brickyard. The 94-acre Terry Brickyard site in the Town of Ulster is owned by Central Hudson. No determination has been made to date of the maximum generating capacity that could be supported by the site. The site was formerly occupied by a brickyard. The Town of Ulster has no zoning ordinances. However, the Ulster County master plan indicates that the portion of the Town of Ulster in which the site is located is designated for future industrial development. The general area of the site has not been identified as a potential candidate for the Greene County Nuclear Power Plant.

1.100 Greene Point. The Greene Point site occupies 348 acres in the Town of Catskill. The site is owned by Central Hudson and is in proximity to the Cementon site selected for the Greene County Nuclear Power Plant. There are no zoning ordinances or master plans that indicate any preferred type of development for the area in which the site is located.

1.101 Easton. The Easton site is owned by Niagara Mohawk and is located in Washington County, on the east bank of the Hudson River directly across from the Saratoga National Historical Park. The site was originally purchased for a nuclear power plant, but the project did not materialize. The ultimate generating capacity that the site can support is estimated to be 600 megawatts. The site is well to the north of the Albany-Troy area.

Other Future Developments

1.102 On 27 October 1965, the 89th Congress authorized the Northeastern United States Water Supply (NEWS) Study and authorized the Secretary of the Army, acting through the Chief of Engineers, to prepare plans to meet the long-range water supply need of the Northeast in cooperation with Federal, State and local agencies.

1.103 The Hudson River Project is designed to operate intermittently and to utilize directly the flows of the Hudson River to supplement an existing regional water supply system during periods of deficit and to expand the conveyance system in New York City and Nassau County. The project would involve the construction of a water intake structure, pumping station, water treatment facility and a tunnel through deep rock. Water would be withdrawn from the Hudson River at a maximum rate of 950 million gallons per day, increasing the safe yield of the supply system by 400 million gallons per day. The project intake would be above (River) Mile Point 86 and below Mile Point 95, between Esopus and Rhinebeck, New York. Two tunnel routes on the west bank and one route on the east bank, all leading to Kensico Reservoir in Westchester County, have been considered. Construction would take 8 years and 11 million cubic yards of rock would be excavated. The material excavated could be used for aggregate or for reclamation of abandoned quarries and gravel pits. The project would also entail completion of portions of New York City Water Tunnel No. 3 and rehabilitation of an existing pipeline between the New York City system and Nassau County. A draft environmental statement has been prepared by the North Atlantic Division, U.S. Army Corps of Engineers and filed with the Council on Environmental Quality (U.S. Army, 1977).

CHAPTER 2

ENVIRONMENTAL SETTING OF THE PROJECT

2.01 The environmental setting of the Bowline Point Generating Station is defined broadly as the lower valley of the Hudson River, a 150-mile corridor extending from the Battery on Manhattan to the Federal Dam at Troy, New York. An extensive study area has been selected expressly to assess both the localized impacts due to the Bowline Point station and the cumulative impacts of other existing major power plants on the Hudson River. As will become evident, there are reasons to suggest that the study area constitutes a distinct natural and ecological system. Further, the region is one in which impacts and resources--physical, biological and human--can be related meaningfully.

2.02 The study area is composed of the counties in New York and New Jersey that lie on both banks of the Hudson River over its tidal portion (Figure 2-1). In New York, these counties are Albany, Rennselaer, Greene, Columbia, Ulster, Dutchess, Orange, Putnam, Rockland and Westchester and, in New Jersey, Bergen and Hudson Counties. Wherever appropriate, the City of New York is treated as a single entity within the study area.

GENERAL

2.03 The Hudson River begins as a small stream flowing out of the Lake Tear in the Clouds on Mount March in Essex County, New York. Its entire length of 306 miles lies in the State of New York. From its source 4,322 feet above sea level in the Adirondack Mountains, the river winds for more than 100 miles in a south-southeasterly direction to Corinth, then east to Glens Falls and neighboring Hudson Falls. From there it flows for 45 miles almost directly south to the head of the tide at the Federal Dam at Troy, about 150 miles upstream of its mouth. Below Troy, the river passes through an industrial and agricultural area and enters the colorful Hudson Highlands region about 60 miles south of Albany. For 16 miles it winds through a narrow valley with high cliffs rising steeply from both shores. The river widens at Indian Point and reaches its greatest width of 3 1/2 miles at Haverstraw Bay. Continuing south, the river is bordered to the west by the sheer cliffs known as the Palisades and widens into upper New York Bay at the Battery on the southern tip of Manhattan Island.

2.04 The Hudson River is one of the major commercial and recreational waterways in the northeastern United States. The U.S. Army, Corps of Engineers, maintains a channel in the river as far north as Waterford. There the Hudson River is joined by the New York

SITE AREA

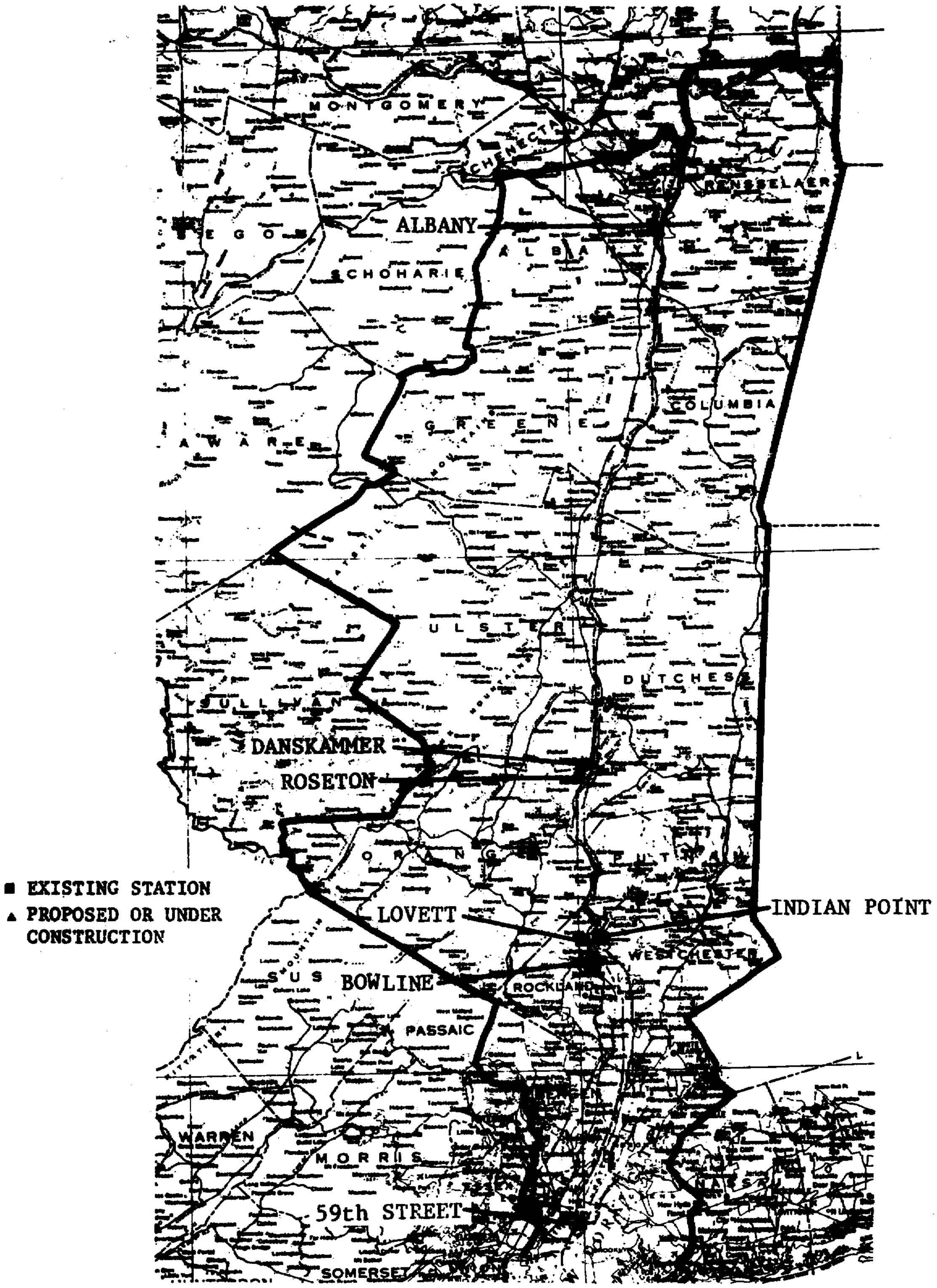


FIGURE 2-1

STUDY AREA AND LOCATION OF EXISTING STEAM-ELECTRIC POWER PLANTS

State Barge Canal, a 500-mile system of canals and riverways that links the lower Hudson to the Great Lakes and, through Lake Champlain, to the St. Lawrence River. Connections are provided to Utica, Syracuse, Rochester, Cayuga Lake and Seneca Lake. The Hudson River is navigable by small oceangoing vessels as far as Albany, and the New York State Barge Canal is navigable by shallow draft vessels. The waterways are heavily traveled by commercial vessels, carrying principally petroleum and petroleum products, sand, gravel, crushed rock and coal. Pleasure boat traffic is considerable during the warmer months, but passenger service on the river is limited to excursion trips operating from the New York City area. The lower river is open year-round to Albany and the navigation season is 12 months for oceangoing vessels and 8 months for barges.

2.05 Settlement of the Hudson River valley by the Dutch began in the mid-1620's, following the discovery of the river by the Florentine navigator Giovanni da Verrazano in 1524 and the later exploration in 1609 of Henry Hudson, an English sea captain employed by the Dutch West India Comapny. Fortified trading posts were established in the area of present day Albany and New York City. The small colony of New Amsterdam on the southern tip of Manhattan grew within the first few years of settlement and its safe harbor saw increasing numbers of commercial vessels plying the coastal trade between New Amsterdam and English settlements in New England and Virginia. The harbor and river, by early accounts, teemed with salmon, striped bass, sturgeon and shellfish.

2.06 Growth of the hinterlands was slow throughout the colonial period but increased rapidly in the 19th century. Robert Fulton established steam navigation in North America with the maiden voyage of the Clermont on the Hudson River in 1807. Completion of the 363-mile Erie Canal between Albany and Buffalo in 1825 had a profound influence on the development of the state, providing, among other things, cheap transportation for the agricultural and manufactured products from western New York and beyond to the Atlantic seaboard. The transportation system of the state was further expanded and reinforced in the 1850's by the consolidation of several small rail lines into the New York Central Railroad running between Albany and Buffalo. Albany was next linked to New York City by the New York and Harlem Railroad and the Hudson River Railroad. Today's principal transportation corridors and lines of communication were forged.

2.07 Industry prospered over the same period along the lower Hudson River. The river towns of Hudson, Poughkeepsie and Newburgh owed their early prosperity to the whaling fleets and processing of whale products. Other industries soon developed and other settlements along the river grew in importance as centers of industry and commerce, among them Tarrytown, Nyack, Ossining, Haverstraw, Peekskill, Beacon, Kingston, Saugerties, Catskill, Troy, Cohoes and Glens Falls. Industries that became established included quarrying and brickmaking, lumbering, fishing, leathermaking and the storage of ice cut from the river in winter. Some of the industries vanished and other developed during the 20th century. Mushrooms were cultivated where ice once was stored, and sawmills began disappearing as lumbering in virgin forests receded further into the mountains. Quarrying of bluestone and cement manufacturing became important industries. The availability of water and increasing demand for electrical energy as the lower Hudson River valley grew into one of the nation's major centers of manufacturing lead to the siting of steam electric plants on the river since the earliest years of the electric utility industry. Transmission lines become established roughly along the major transportation routes as individual utilities merged gradually to form the integrated supply network that exists today.

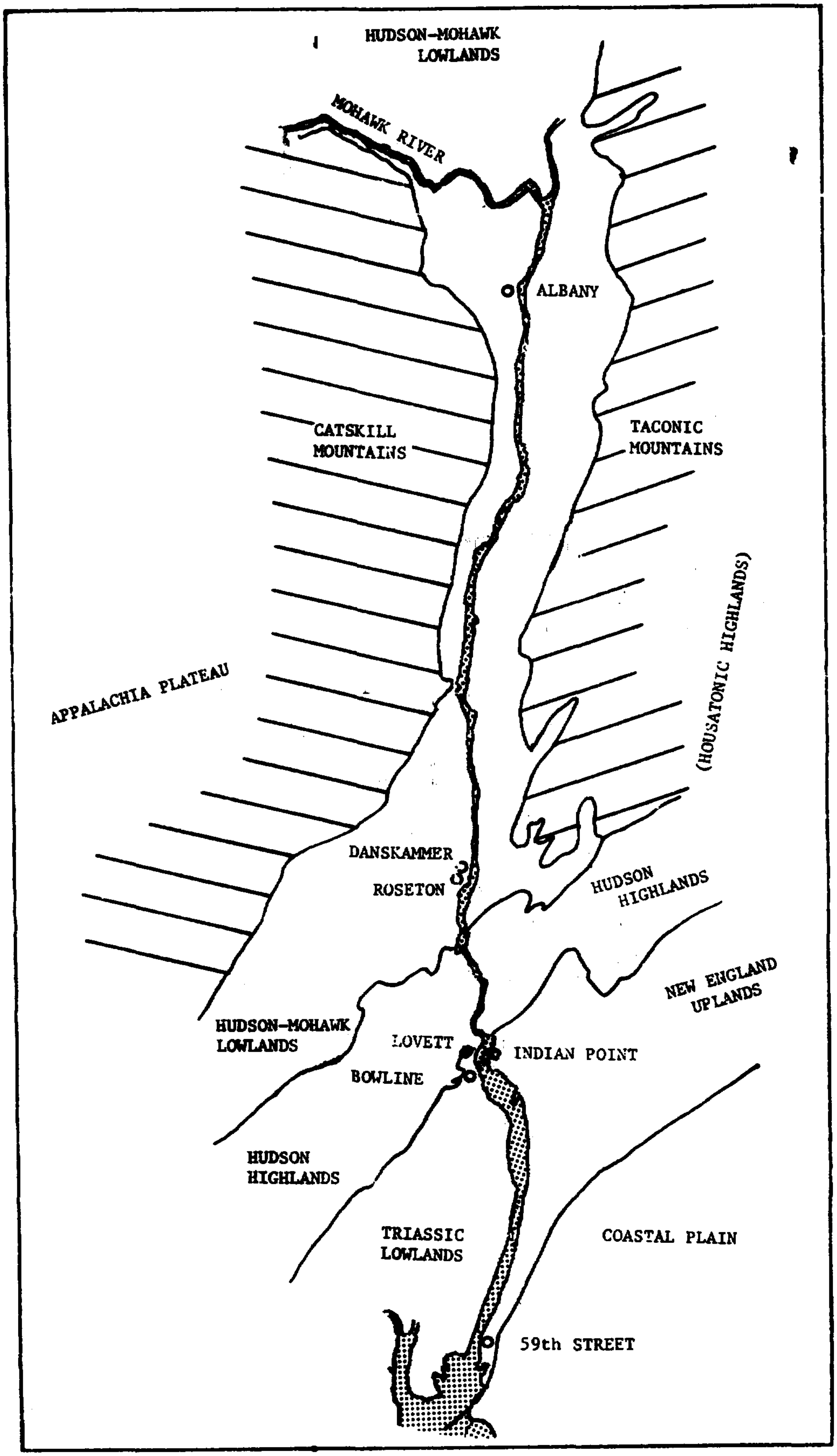
PHYSICAL SETTING

2.08 The Hudson River estuary extends over an area of approximately 6,700 square miles. Below Albany, the land becomes open country except where the Catskills and the Hudson Highlands cut through the Hudson Valley. South of the Highlands, the basin again becomes open country with the high cliffs of the Palisades forming the west bank of the Hudson River.

Physiography

2.09 The entire Hudson River Basin lies in six physiographic provinces--St. Lawrence-Champlain Lowlands, Adirondack Highlands, Hudson-Mohawk Lowlands, Appalachian Uplands, New England Uplands and Triassic Lowlands (Roughton et al., 1962). The St. Lawrence-Champlain Lowlands Province includes the St. Lawrence River Valley northeast of the Thousand Islands, the Low rolling hills that border this valley to the south, and the Lake Champlain Valley. The Adirondack Highlands Province includes the highest mountains in New York State, especially in the High Peak areas of the east-central Adirondack Mountains. Both these provinces lie beyond the study area; the Hudson River estuary lies within portions of the remaining four provinces, as shown in Figure 2-2.

2.10 The Hudson-Mohawk Lowlands province is a northward extension of the Valley and Ridge Province of eastern North America. Topography of the lowlands has been developed by erosion of weak rock outcrop belts that, in the case of the Mohawk Lowlands, lie between the Adirondacks and a series of steep limestone escarpments known as the Helderbergs. The Hudson Lowlands lie between the Catskills to the west and the metamorphosed shale hills of the Taconic Mountains



Source: Broughton et al., 1962.

FIGURE 2-2

PHYSIOGRAPHIC PROVINCES OF THE STUDY AREA to the east. For the most part, the lowlands have low elevations and relief.

2.11 The Catskill Mountains form the eastern fringe of the Appalachian Uplands, a major area of the State of New York and a part of the Appalachian Plateau. Relief is high to moderate throughout the Appalachian Uplands, the highest peak being Slide Mountain (4,202 feet) in the Catskill Mountains.

2.12 The New England Uplands Province is an area of great geological complexity and diversity. The area encompasses the Hudson Highlands and the hilly country (Taconic Mountains) between the Hudson River and the Massachusetts, Connecticut and Vermont state lines. Rocks in this province are either metamorphic or igneous, and the land forms show a close relationship to the relative durability of these rocks. The Hudson Highlands, a northeast trending upland of Precambrain rocks, are an extension of the New Jersey Highlands to the south and continue into the Housatonic Highlands to the north. The Hudson Highlands have the greatest relief within the province, with elevations ranging from 800 feet below sea level (bedrock of the Hurson River Valley) to more than 1,600 feet. Most of the ridges and valleys in the Hudson Highlands follow the northeast-southwest strike of the metamorphosed rocks so that strong topographic linearity characterizes this part of the province. The Taconic Mountains have a general north-south trend dependent on the strike of the schist that forms the hills and the limestone in the valleys. An exception is the Rensselaer Plateau, a rolling plateau surface with relief of more than 500 feet. This area, about 20 miles long (north-south) by 9 miles wide (east-west) is held up by the resistant Rensselaer graywacke.

2.13 The Triassic Lowlands area is unique in New York State. The portion of the province within the state lies entirely in Rockland County and is bounded on the east by Palisades sill and on the north by the sill and the Triassic border fault. Shales and sandstones lie both over and under the diabase sill, but those beneath are mainly covered by Hudson River waters. Drainage in the overlying shales is to the south and is generally controlled by north-south joints. The oustandings feature of the province is the Palisades, a north-south escarpment developed on the diabase sill that forms the west bank of the Hudson River from Nyack south to Staten Island. The scarp has been cut in several places by faults along which erosion has developed narrow cross valleys.

2.14 The geomorphology of the Hudson drainage basin has been influenced substantially by the glaciations of the Pleistocene age. The river valley, which paralleled the general north-south direction of ice advances and retreats, was deepened into a typical glacial trough with U-shaped cross-section, leaving tributaries hanging high above the new valley floor. During glacial retreat and subsequent flooding with the rise in sea level, the deep trench, in places up to 750 or 800 feet in depth, was partially filled in by debris and glacial till. The trench, in its present form, is the Hudson River Channel.

2.15 The Bowline Point Generating Station is located in the Triassic Lowlands. Other generating facilities on the Hudson River north of the Hudson Highlands, including the Roseton facility, lie in the Hudson-Mohawk Lowlands.

2.16 The Northeastern Region of the United States, defined as New England and New York by the National Oceanic and Atmospheric Administration for the purpose of of listing and describing earthquakes, contains zones of relatively high seismic activity (U.S. Department of Commerce, 1973a). New York and Massachusetts have experienced several severe shocks. This region is affected also by large earthquakes originating in adjacent Canada, principally in the St. Lawrence Valley and the Laurentain Trough. Earthquakes in the region may be explained by the readjustment of the crust following the recent Ice Age. Some geologists suggest that the earth's crust, deformed by the ice load during glacial periods, is gradually returning to its normal position. Adjustments may occur at great depths without producing major surface faulting (U.S. Department of Commerce, 1973a).

2.17 The general area of major seismic risk in New York lies to the north of a line extending from the southwestern corner of the state on Lake Erie to the New York-Vermont state line on the Canadian border. All of southeastern New York up to a point south of the Albany-Troy area and part of the Southern Tier of the state is in an area of minor risk. The remainder of the state is an area of moderate seismic risk (U.S. Department of Commerce, 1976a). Thus, the study area lies within a zone considered to be of minor seismic risk, with the exception of Albany and Rensselaer Counties, which mark the transition into a zone of moderate seismic risk.

Climate

2.18 The climate* of the Hudson River Estuary is characterized as humid continental, the type that prevails throughout the northeastern U.S. Dominant continental characteristics stem from the frequent invasions of cold, dry air masses from the northern interior of the continent alternating with warm, humid air transported by

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*Material on climate in the study area is derived mainly from Pack, 1972.

south and southwesterly winds from the Gulf of Mexico and adjacent tropical waters. A third flow of air affects the climate of New York, particularly in the southeastern portion. A great air mass flows inland from the North Atlantic Ocean and produces cool, cloudy and damp weather. Although important, the maritime influence is secondary to the more prevalent air flows across the continent.

2.19 Average annual mean temperatures throughout the state vary between 40 F in the Adirondack Mountains to near 55 F in the New York City area. Average January temperatures range from 16 F the Adirondacks to 26 F in the lower Hudson River Valley. The moderating influcence of the Atlantic Ocean is such that New York City experiences subzero minimum temperatures in two or three winters out of 10, with low temperatures generally near -5 F. The lower portions of the Hudson River Valley have rather warm summers with periods of high, uncomfortable humidity. Summer daytime temperatures range from the upper 70s to the mid-80s. Temperatures of 90 F or higher occur from late May to mid-September throughout the Hudson River Estuary. The New York City area and most of the Hudson River Valley record an average of 18 to 25 days with such temperatures during the warm season. While temperatures in excess of 100 F are rare, many weather stations in the southern portion of the state have recorded temperatures of 100 F to 105 F on occasions. In the Adirondack Mountains the summer climate is considerably cooler, adding to the area's attractiveness as a year-round resort.

2.20 The average annual precipitation in the Hudson River basin is 42 inches, generally evenly distributed throughout the year. No distinctly dry or wet seasons occur regularly from year to year. However, long-term records indicate that the greatest precipitation occurs in the spring and fall. Since the drought of 1964, summer rainfalls in excess of the average 4 inches per month have been recorded in the Hudson River Valley. Annual precipitation may be as high as 50 inches in the Catskills. The Catskill highlands in Ulster (and Delaware and Sullivan Counties) record heavy snow accumulations averaging 100 to 120 inches per year. The moderating influence of the Atlantic Ocean reduces the snow accumulation to 25 to 35 inches in the New York City area. Minimum seasonal snowfalls of 40 to 50 inches occur near the Hudson River in Orange, Rockland, and Westchester Counties and upstream to the southern portion of Albany and Rensselaer Counties.

2.21 Although major floods are relatively infrequent, the greatest potential for flooding occurs throughout the State in the early spring when subatantial rains may combine with rapid snow melt to produce heavy runoff. Several of these floods have occurred since the turn of the century in the river basins of southern and eastern New York. At other times of the year damaging floods occur after prolonged periods of rainfall. Examples in recent years are the floods in the lower Hudson River Valley in May 1968 and in the Catskill Mountains in July 1969. In addition, the New York City area and other heavily urbanized areas are subject to severe flooding of highways, streets, and low-lying ground.

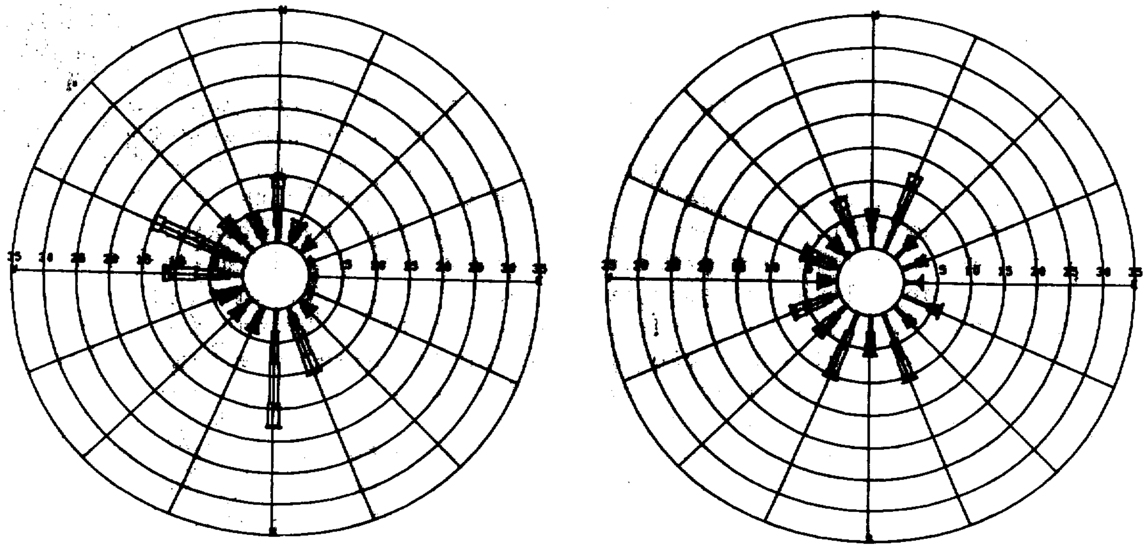
2.22 The prevailing wind is generally from the west throughout all of New York State. A southwest component become evident during the warmer months while a northwest component is characteristic of the colder half of the year. Wind patterns within the Hudson River estuary, however, are substantially influenced by terrain, particularly where relatively pronounced differences in elevation occur between the valley and adjacent ridges. This influence is such that winds on and above the river are often upstream by day and downstream by night. Annual wind roses pertaining to three selected locations within the study area are shown in Figure 2-3.

2.23 Annual wind roses derived from meteorological observations at the Bowline Point and Roseton generating stations (Orange and Rockland, July 1976; Central Hudson, 1976) are shown in Figure 2-4. The differences in wind patterns prevailing at the two sites reflects the strong influence of topography. Local winds at Bowline Point are predominantly from the northwest quadrant over the year, with a secondary maximum in the distribution due to the southerly winds of the summer months. Further details of wind direction frequencies by calendar quarter and stability class, as observed at the Bowline Point station between June 1975 and May 1976 (Orange and Rockland, 1976) are summarized in Table 2-1. Dominant wind directions at Roseton are north-northeast and south-southwest, roughly parallel to the river channel at the site. Available information derived from observations at the Roseton Generating Station between December 1974 and February 1975 (Central Hudson Gas and Electric, 1975) is given in Table 2-2.

Hydrology

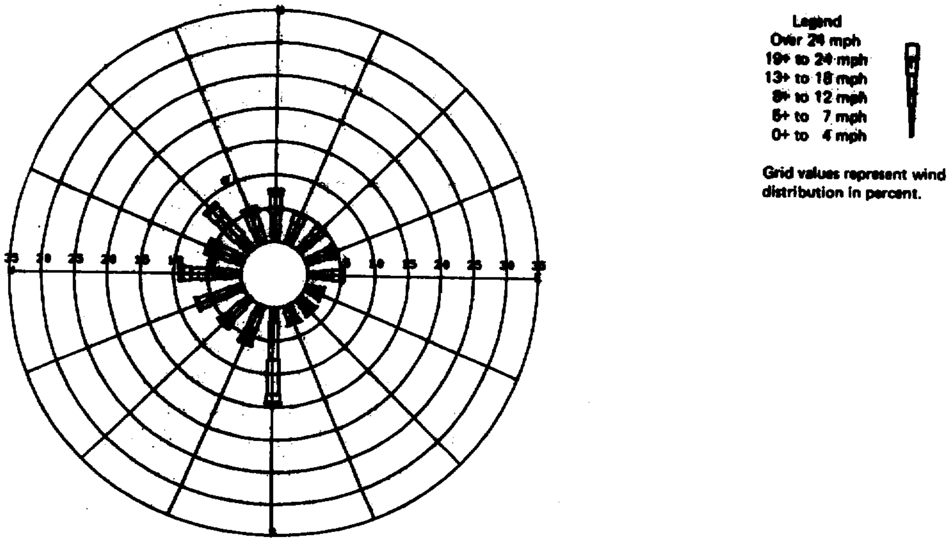
2.24 The Hudson River drains a total area of 13,400 square miles, most of which lies within New York State, with small portions of the basin extending into Vermont, Massachusetts, Connecticut and New Jersey (U.S. Department of the Interior, 1972). Approximately 8,100 square miles or 60 percent of the drainage basin is upstream of the Federal Dam at Troy. The remaining portion drains into the estuarine portion of the river.

2.25 South of the Hudson-Mohawk confluence, the Hudson River is joined by only three major tributaries, namely, the Wallkill River



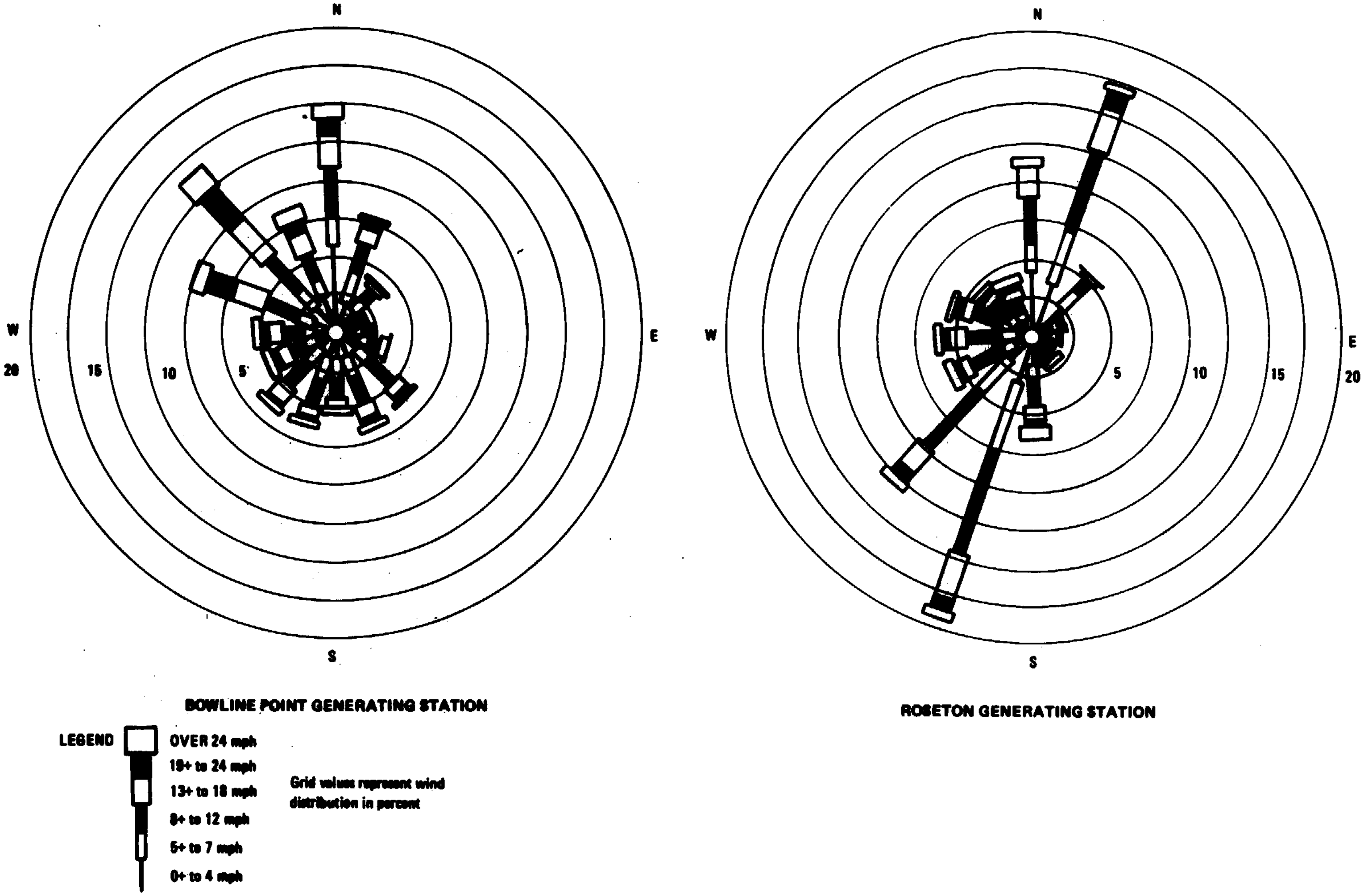
ALBANY
(1960-1964)

POUGHKEEPSIE
(1950-1954)



NEW YORK CITY (J. F. KENNEDY AIRPORT)
(1966-1970)

FIGURE 2-3
ANNUAL WIND ROSES AT SELECTED LOCATIONS IN THE STUDY AREA



Sources: Orange and Rockland, 1976; Central Hudson, 1976

FIGURE 2-4

ANNUAL WIND ROSES AT THE BOWLINE POINT AND ROSETON SITES

TABLE 2-1

QUARTERLY WIND DIRECTION FREQUENCIES BY STABILITY CLASS, JUNE 1975-MAY 1976, AT THE BOWLINE POINT GENERATING STATION

STATION	STABILITY (JUNE-AUGUST 1975)						STABILITY (SEPTEMBER-NOVEMBER 1975)					
	UNSTABLE (25.4%)		NEUTRAL (49.4%)		STABLE (25.2%)		UNSTABLE (11.2%)		NEUTRAL (55.2%)		STABLE (33.7%)	
Bowline Tower, 100-foot level	N	10.6	SSE	12.3	W	10.2	ESE	15.2	N	10.2	WNW	27.0
	NNE	10.1			WNW	33.8	NW	17.7	SSE	9.9	NW	22.9
					NW	21.2			WNW	11.0		
									NW	15.7		
	UNSTABLE (25.5%)		NEUTRAL (50.7%)		STABLE (23.8%)		UNSTABLE (10.9%)		NEUTRAL (55.2%)		STABLE (33.9%)	
Bowline Tower 200-foot level	N	11.2	SE	10.4	WNW	16.3	NW	17.4	N	9.5	WNW	9.0
	NW	10.0	SSE	13.3	NW	23.7	SSE	12.7	NNE	10.4	NW	16.8
					NNW	11.2			SSE	10.0	NNW	18.6
									WNW	10.5		
									NW	15.6		
	UNSTABLE (25.9%)		NEUTRAL (48.1%)		STABLE (26.0%)		UNSTABLE (11.8%)		NEUTRAL (55.3%)		STABLE (32.9%)	
Bowline Tower, 350-foot level	NNE	13.0	SSE	10.1	WNW	10.0	SE	16.1	N	9.4	N	9.6
					NW	13.9	NW	14.7	NNE	10.4	NW	9.0
					NNW	14.1			SSE	11.8	NNW	9.0
					N	11.8			NW	11.1		

STATION	STABILITY (DECEMBER 1975-FEBRUARY 1976)						STABILITY (MARCH-MAY 1976)					
	UNSTABLE (5.4%)		NEUTRAL (74.1%)		STABLE (20.5)		UNSTABLE (1.2%)		NEUTRAL (65.4%)		STABLE (33.2%)	
Bowline Tower (L), 100-foot level	N	15.6	N	13.5	WNW	16.6	N	33.8	WNW	15.1	SE	15.0
	NNE	22.9	WNW	13.8	NW	26.9	NNE	33.8	NW	21.5	NW	16.6
	NE	9.4	NW	25.7			NE	14.8				
	WNW											
	UNSTABLE (4.8%)		NEUTRAL (74.7%)		STABLE (18.5%)		UNSTABLE (1.2%)		NEUTRAL (65.4%)		STABLE (33.2%)	
Bowline Tower (L), 200-foot level	N	15.7	N	10.1	NNW	17.9	N	44.4	WNW	20.9	SE	13.2
	NNE	22.9	NNE	10.8			NNE	29.6	NW	17.1		
	NE	10.0	NW	28.5								
	NW	17.1	NNW	11.5								
	UNSTABLE (4.9%)		NEUTRAL (74.6%)		STABLE (20.5%)		UNSTABLE (1.2%)		NEUTRAL (64.4%)		STABLE (34.2%)	
Bowline Tower, 350-foot level	N	31.0	N	18.0	N	9.7	N	44.4	WNW	11.2	SE	11.0
	NNE	19.0	WNW	11.8	SSW	9.4	NNE	37.0	NW	19.1		
	WNW	9.5	NW	19.5	NNW	11.1						
	NNW	11.9	NNW	9.9								

All frequencies in percent.

Source: Orange and Rockland, 1976.

TABLE 2-2

PREDOMINANT WIND DIRECTION FREQUENCIES BY STABILITY CLASS AT ROSETON GENERATING STATION, DECEMBER 1974 THROUGH FEBRUARY 1975

STATION	STABILITY					
	UNSTABLE (2%)		NEUTRAL (58%)		STABLE (40%)	
Roseton, 50-foot level	NNE	13	NNW-NNE	25	N-NNE	13
	SSW-WSW	52	SSW-WSW	36	SSW-SW	30
	NW	6	W	9	CALM	26
	CALM	9	CALM	7	OTHER*	31
	OTHER*	20	OTHER*	23		
Roseton, 280-foot level	NNE	24	N-NNE	22	N-NNE	16
	SSW-WSW	38	SSW-WSW	34	SSW-SW	37
	W-NW	18	W-WNW	17	CALM	10
	OTHER*	20	OTHER*	27	OTHER*	37

*Indicates the sum of the unlisted wind direction sectors, each less than 5% frequency.

Source: Central Hudson, 1975.

and Kinderhook and Rondout Creeks (U.S. Department of the Interior, 1972). The drainage area of the lower river is generally narrow and confined by geologic barriers such as the Berkshires and the Catskills, the Mid-Hudson ridge of the Appalachian chain, and the Palisades formation.

2.26 Steam gaging records at Green Island, immediately upstream of the Troy lock, show that the yearly average flow of freshwater in the Hudson River exceeds 13,000 cubic feet per second (National Commission on Water Quality, 1975). Monthly and yearly average flows measured at Green Island between 1972 and 1975 (National Commission on Water Quality, 1975; U.S. Department of the Interior 1976) are shown in Table 2-3 together with long-term (1918 through 1973) average flows. As the data indicate, freshwater flows vary considerably over the year with maximum flows occurring generally during the months of March, April and May. Periods of low flow usually begin in June and continue until November.

2.27 The major portion of freshwater flow enters the estuary at its head at Troy. The remaining portion consists largely of contributions by tributaries flowing into the upper reach of the estuary. Runoff from approximately one half of the river basin downstream of Green Island is gaged. The oscillating tidal flow in the estuary can exceed the flow of freshwater by a factor of 10 to 100. During each tidal cycle of 24 hours and 50 minutes, two high tides and two low tides occur, producing a mean tidal range of 4.5 feet at the Battery, 2.7 feet at West Point and 4.7 feet at the Troy Dam (U.S. Department of Commerce, 1972).

2.28 The salinity* of the Hudson River increases gradually with distance moving downstream towards its mouth (Water Information Center, 1976). In the freshwater sectors, chloride ion concentrations ranging from 6 to 30 milligrams per liter (mg/l)** may be encountered as a result of sewage and industrial discharges and runoff from adjacent lands. Values over 30 (mg/l) can be indicative of the first intrusions of seawater. Downstream of the freshwater sectors, chloride concentrations in the river increase to

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*Salinity denotes the dissolved mineral content of seawater and amounts of 34,500 milligrams per liter in the Atlantic Ocean where the Hudson River estuary discharges (Water Information Center, 1976). Six constituents make up 99 percent of the total seawater salinity. The major component is the chloride ion, which accounts for 55.0 percent; other major component ions are sodium (30.6 percent), sulfate (7.4 percent), magnesium (3.7 percent), calcium (1.2 percent) and potassium (1.1 percent).

**For percent purposes, milligrams per liter and parts per million (by weight) may be taken as equivalent units.

TABLE 2-3

MONTHLY AND YEARLY AVERAGE FLOWS OF THE HUDSON RIVER AT GREEN ISLAND FROM 1972 THROUGH 1975 AND LONG-TERM AVERAGES

update?

MONTH	FLOW (CUBIC FEET PER SECOND)				AVERAGE
	1972	1973	1974	1975	1918-1973
October	7,811	7,198	6,332	9,049	7,620
November	7,291	26,081	10,933	17,180	12,970
December	17,000	26,913	34,566	19,380	13,603
January	13,410	26,181	30,730	19,070	12,439
February	10,930	20,368	24,911	19,370	11,708
March	26,860	29,730	30,933	23,680	22,743
April	37,960	34,270	39,973	25,580	31,465
May	40,520	27,540	77,833	20,000	18,469
June	29,630	12,600	10,702	12,970	9,708
July	18,380	10,230	20,127	7,464	6,912
August	7,616	6,180	12,845	8,966	5,342
September	6,309	4,050	13,420	17,030	5,963
Yearly Average	18,643	19,278	26,110	16,610	13,172

*Water year begins in October and ends in September of the following year. For example, water year 1972 began on October 1, 1971, and ended on September 30, 1972.

Sources: National Commission on Water Quality, 1975; U.S. Department of the Interior, 1976.

values between 5,000 to 16,000 mg/l in New York City area and 15,000 to 19,000 mg/l at the outlet to New York Bay.

2.29 In broad terms, the seawater advances and recedes in the river as a wedge. Fresh and seawater at the interface remain relatively well separated when the wedge is located far downstream. Under these conditions the properties of the water at the surface and bottom differ markedly, but the front becomes increasingly diffuse as it progresses towards the middle reaches of the estuary.

2.30 The movement of the salt front in the Hudson River estuary is influenced by several factors, principal among them being the amount of freshwater flow and the tidal surge of saline water from the ocean. The salt front oscillates with each tide in a movement, known as the tidal excursion, that may transfer the salt front upstream by as much ~~as 8~~ miles on the flood tide and almost 10 miles downstream on the ebb tide. The overall mean position of the salt front can travel up or downstream in response to seasonal river flows by as much as 50 or 60 river miles. The upstream movements of the salt front are associated with higher incoming tides and diminishing upland runoffs; conversely, downstream movements are associated with increasing upland flows and lower tides.

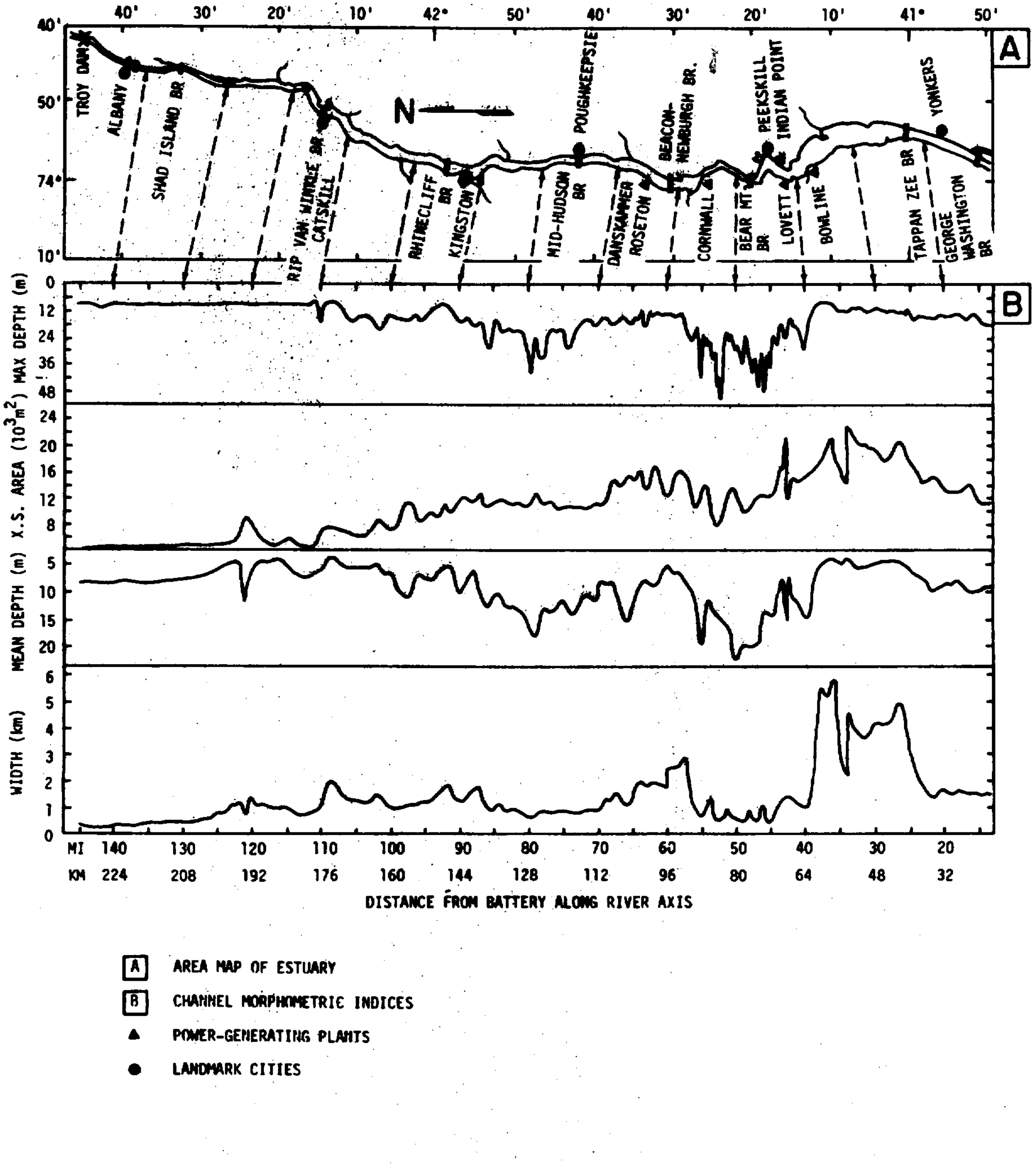
extreme

2.31 Seasonal average profiles of chloride concentrations indicate that the salt intrusion (where the concentration of chloride ions exceed 100 mg/l) reaches Mile Point (river mile) 33 in winter, 36 in spring, 47 in summer and 48 in fall (National Commission on Water Quality, 1976). During years of normal or above normal flow, therefore, the salt front reaches the Bowline Point Generating Station at Mile Point 37.5 only in summer and fall and does not reach the Roseton Generating Station at Mile Point 65.8. The intrusion during periods of abnormally low flows may reach considerably farther upstream. For example, in the drought year of 1964, the salinity front reached as far as Mile Point 82 in the vicinity of Hyde Park.

2.32 An overview of the major morphological characteristics of the lower Hudson River is shown in Figure 2-5 and observations taken in 1974 are summarized in Figure 2-6.

Water Quality

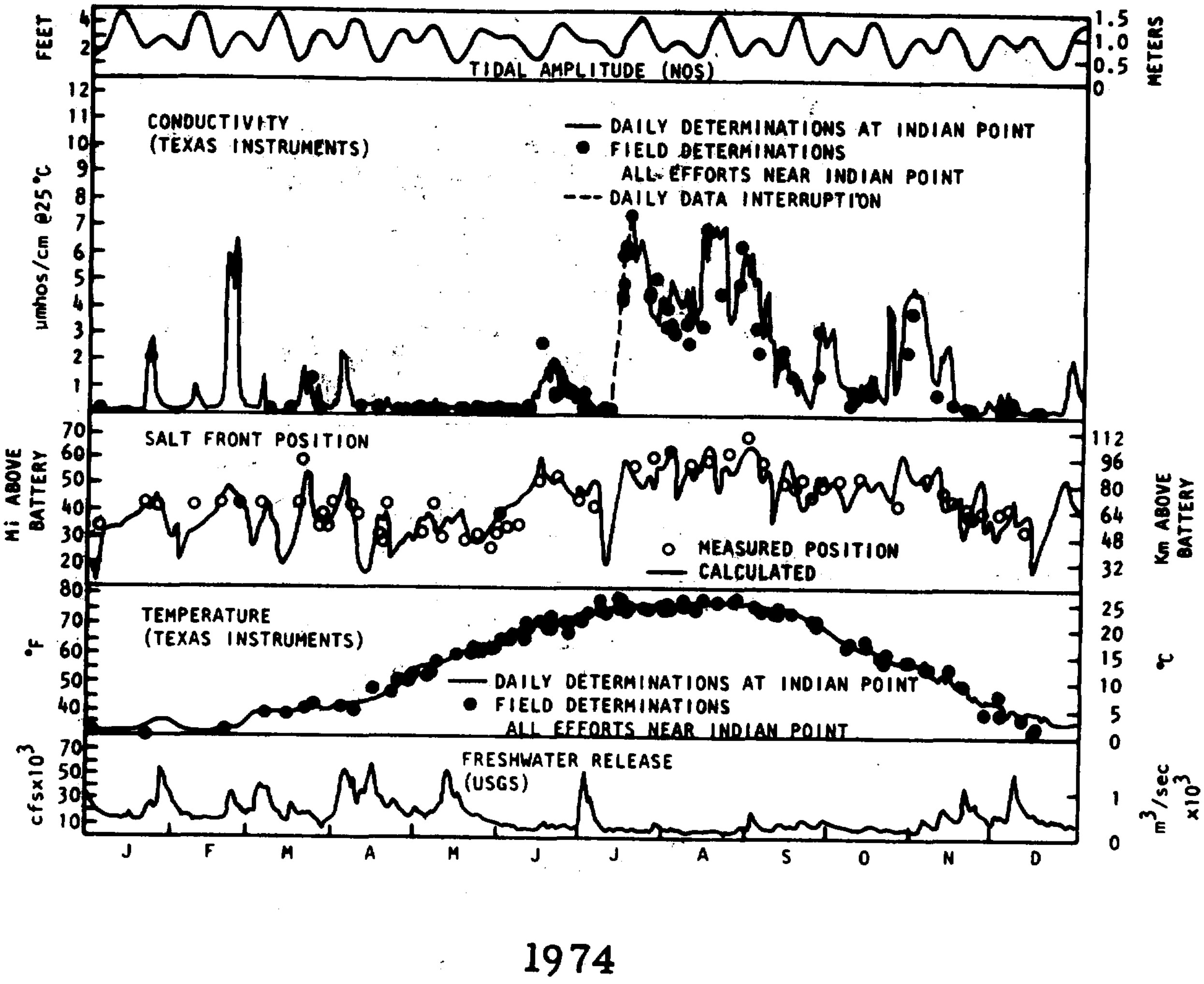
2.33 The quality of the Hudson River waters varies greatly along the estuarine portion of the river. The New York State Department of Environmental Conservation has subdivided the estuary into five segments and characterizes the quality of water in each of these on the basis of criteria developed by the Department (6 NYCRR 700-703). An overview of the classification scheme is given in Figure 2-7. As indicated, water quality in the midportion of the



Source: Texas Instruments, 1975.

FIGURE 2-5

MORPHOMETRIC CHARACTERISTICS OF THE LOWER HUDSON RIVER



Source: Texas Instruments, 1975.

FIGURE 2-6

TEMPORAL DISTRIBUTION OF FRESHWATER RELEASE,
WATER TEMPERATURE, SALT FRONT POSITION, CONDUCTIVITY, AND TIDAL AMPLITUDE
IN THE HUDSON RIVER DURING 1974

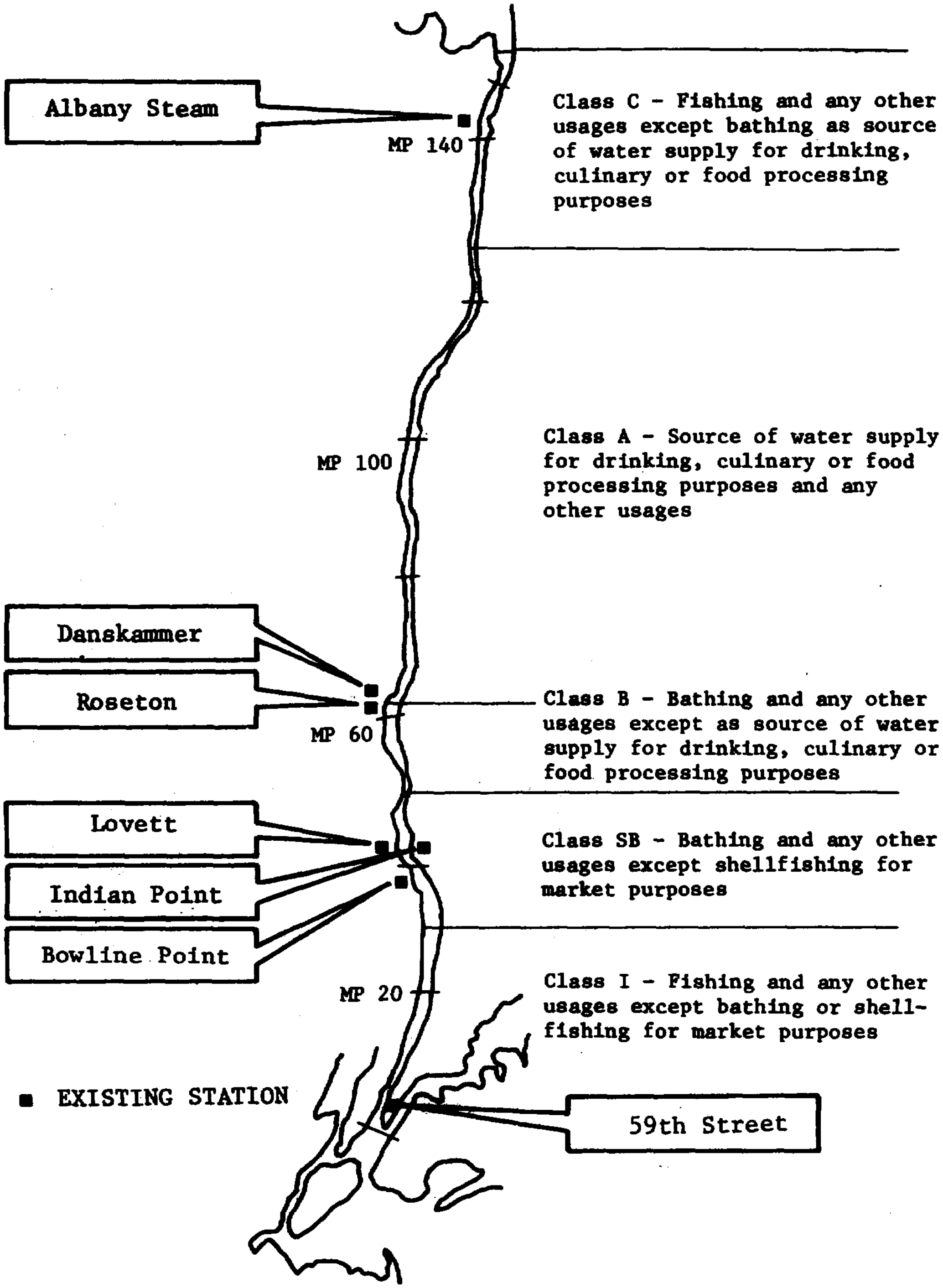


FIGURE 2-7

OVERVIEW OF WATER QUALITY BY NEW YORK STATE STANDARDS
IN THE HUDSON RIVER

estuary is generally good, allowing the unrestricted use of water (including municipal supply) roughly between Mile Points 60 and 125. Water quality upstream of Mile Point 125 to the Albany area deteriorates, rendering the river unsuitable for bathing and as a source of municipal supply. Downstream of Mile Point 60 the estuary is subject to intrusion of saline water and the river becomes unsuitable for municipal supply. Progressively worsening water quality excludes the use of the river for commercial shellfishing downstream of Mile Point 50 as well as bathing downstream of Mile Point 30 through to the Battery.

update?

2.34 Municipal discharges of sewage into the river are the principal causes of poor water quality downstream of Albany and in the New York City area (National Commission on Water Quality, 1976). In spite of substantial reductions in waste loads since 1967, disolved oxygen levels in these portions of the river fall below the critical level of 4.0 milligrams per liter* during summer and periods of extremely low flow (National Commission on Water Quality, 1976). A maximum concentration of coliform bacteria occurs in the New York City area where a count of 122,600 cells per 100 milliliters has been reported (National Commission on Water Quality, 1976). Undesirable high coliform counts are characteristic of approximately one-half of the Hudson River within the study area (National Commission on Water Quality, 1976; U.S. Council on Environmental Quality, 1976). Although the elevated bacteriological content of river waters is attributed for the most part to point sources, the contributions of stormwater runoff and combined sewer discharges are thought to be appreciable (National Commission on Water Quality, 1976).

2.35 Dissolved oxygen levels in the remainder of the estuary remain above 4.0 milligrams per liter. Although 5-day biochemical oxygen demand of the river waters is generally not high, being less than 4 milligrams per liter, the corresponding chemical oxygen demand is at a substantially higher level of 12 to 35 milligrams per liter, suggesting the presence of refractory or nonbiodegradable organic material (National Commission on Water Qualtiy, 1976).

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*A level of 4.0 milligrams per liter of dissolved oxygen is considered as a generally applicable minimum needed to ensure survival of aquatic life (U.S. Council on Environmental Quality, 1976). Other criteria adopted as benchmark values by the Council on Environmental Quality in assessing water quality trends of U.S. rivers are as follows: fecal coliform bacteria--200 cells per 100 milliliters (health protection of swimmers), biochemical oxygen demand--5 milligrams per liter, total phosphorus--0.1 milligram per liter (prevention of nuisance algae growth), and total nitrogen--1.0 milligram per liter (U.S. Council on Environmental Quality, 1976).

Nutrients

2.36 Due principally to the inflow of sewage from New York City and Albany areas, concentrations of nitrogen and phosphorus in the Hudson River estuary are often at levels higher than those generally considered to be indicative of eutrophication. Phosphorus levels exceed 0.1 milligrams per liter over almost the entire length of the river within the study area, and nitrogen levels are above 1 milligram per liter over approximately one-half that length (National Commission on Water Quality, 1976). In spite of high nutrient levels, the manifestations of eutrophic conditions are limited to occasional nearshore blooms of algae. Factors that tend to control algae productivity are the relatively short growing season and rapid flow of the river. Other factors, such as turbidity (not especially high in the Hudson River), elevated concentrations of suspended colloidal particles and abundance of organisms, act as barriers to light penetration and may further control the growth of algae (National Commission on Water Quality, 1976).

Toxic Substances

2.37 Concentrations of heavy metals in the Hudson River are generally below levels that are lethal to aquatic organisms and relatively high concentrations of iron, copper and lead have been reported (National Commission on Water Quality, 1976). The extent to which residual quantities of pesticides may be present in the waters of the Hudson River has not been determined. In view of the small portion of land devoted to agriculatural uses within the study area, pesticides are considered as a relatively minor health hazard in comparison to sewer overflows and storm runoff from urban areas (National Commission on Water Quality, 1976). The confirmed presence of polychlorinated biphenyl (PCB) compounds in the waters, sediments, and fishes of the Hudson River (New York State Department of Environmental Conservation, 1975; 41 FR 8409, 26 February 1976) has led to a ban on most commercial fishing in the Hudson River as of 26 February 1976 (6 NYCRR Section 12.19) and advice to sports fishermen to restrict the intake by individuals of fish from the Hudson to no more than one meal per week. Regulations promulgated by the U.S. Environmental Protection Agency (42 FR 6532, 2 February 1977; 40 CFR 129.105) now prohibit the discharge of polychlorinated biphenyls in liquid effluents from plants that manufacture these compounds or electrical equipment (transformers and capacitors). Nonetheless, substantial quantities of polychlorinated biphenyls remain in the river, and studies are underway to assess the severity of the problem and the means available to remove and dispose of the compounds (Kopp, 1977). There are presently no estimates of how soon the ban on commercial fishing might be partially or totally lifted or when residual quantities of polychlorinated biphenyls in the river might be substantially reduced.

Temperature

2.38 The waste heat rejected by steam electric generating facilities on the Hudson River estuary constitutes the largest component of the artificial thermal load imposed on the river (National Commission on Water Quality, 1976). Field surveys and numerical simulations (Chapter 4 and Appendix E) indicate that the temperature of the river is increased, both locally in the vicinity of the power plant and in certain portions of the estuary as a result of cumulative effects.

Salinity

2.39 The Hudson River waters are generally characterized as fresh in the estuary south of Troy, becoming brackish below Poughkeepsie and saline below Peekskill (U.S. Department of the Interior, 1972). As previously discussed, the gradation in salinity reflects the intrusion of oceanic waters into the estuary.

Abatement of Waterborne Discharges

2.40 The anticipated reduction in point source loads under succeeding abatement levels required by the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) will largely alleviate many of the current water quality shortcomings in the lower Hudson River (National Commission on Water Quality, 1976). The law stipulates that contaminants in the liquid effluents from plants in most major industrial categories be reduced to levels that reflect the application of the "best practicable control technology currently available" by 1 July 1977 and the "best available technology economically achievable" by 1 July 1983. Municipal sewage discharges must receive secondary treatment by 1977 and best practicable treatment by 1983. The ultimate goal is to eliminate the discharge of all pollutants into navigable waterways by 1985.

2.41 Projections (National Commission on Water Quality, 1976) indicate that implementation of the 1977 requirements (application of best practicable technology) will result in large improvements in the dissolved oxygen levels in the New York harbor area. Near Albany, second treatment of municipal wastes would not be sufficient to maintain the level of dissolved oxygen above 4.0 milligrams per liter during periods of extremely low flow. In midestuary (above Haverstraw Bay and below Catskill), the 1977 requirements are expected to produce only small improvements in dissolved oxygen levels.

2.42 Point sources are the major contributors of nutient levels in the lower Hudson River. Nonpoint sources, because of limited agriculture in the basin, make relatively minor contributions (National Commission on Water Quality, 1976). Projections indicate that the 1977 and 1983 requirements will have little effect on nutrient levels in river waters. On the other hand, the elimination of all point discharges would reduce the nutrient concentrations to low values, estimated to be 10 to 20 percent of those currently prevailing (National Commission on Water Quality, 1976).

2.43 Closed cycle cooling systems, assuming these are installed at all eligible generating stations under the 1983 requirements, would substantially reduce the artificial thermal load on the lower Hudson River (Section 4 and Appendix E).

Ref/ settlemt agreemt

2.44 The 1977 requirement for secondary treatment of municipal waters is expected to result in a drastic reduction of coliform bacteria in the Hudson River. Waters would meet water quality standards applicable to swimming along the entire estuary except perhaps during periods following heavy downpours. The 1983 and 1985 requirements could lead to further reductions, but it appears doubtful that counts lower than 100 to 200 cells per 100 millilters will be attained due to the substantive contributions of nonpoint sources (National Commission Water Quality, 1976). Concentrations of heavy metals are expected to be reduced only slightly by the 1977 and 1983 requirements, since industrial discharges represent relativley minor sources of these contaminants in comparison to storm water runoff in urban areas (National Commission on Water Quality, 1976).

Air Quality

2.45 The Hudson River estuary lies within two Air Quality Control Regions (AQCRs) established by the U.S. Environmental Protection Agency (40 CFR 81). These regions, outlined in Figure 2-8, are the New York-New Jersey-Connecticut Interstate Region and the Hudson Valley Intrastate Region. Air quality within each region is characterized by the U.S. Environmental Protection Agency in accordance with measured concentrations of sulfur oxides, particulate matter, carbon monoxide, nitrogen dioxide and photochemical oxidants. The numerical criteria given in Table 2-4 provide a basis for classifying a particular region with respect to each of these pollutants. A Class I designation denotes the lowest level of air quality, Class III the highest. The New York-New Jersey-Connecticut Region is currently characterized as Class I with respect to all five categories of pollutants. The Hudson Valley Intrastate Region is characterized as Class I for particulate matter, Class II for sulfur oxides and Class

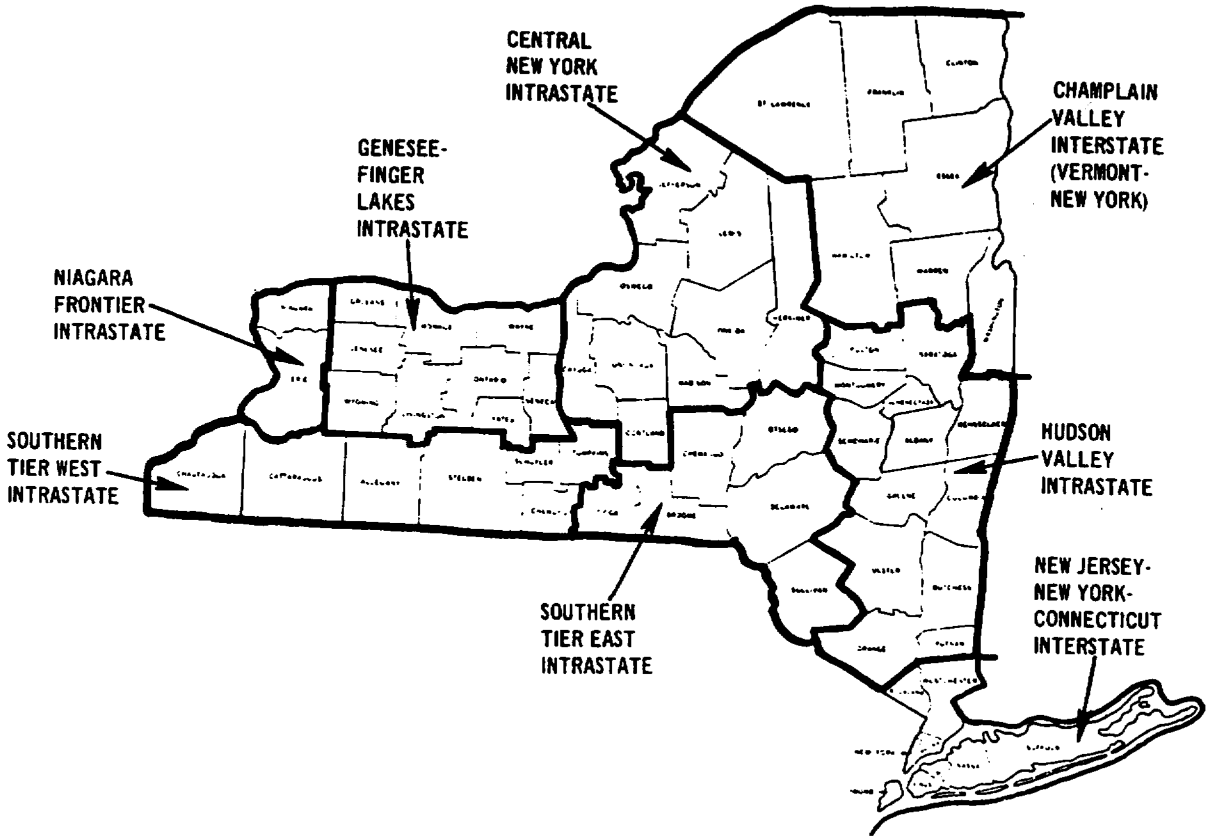


FIGURE 2-8

AIR QUALITY CONTROL REGIONS OF NEW YORK, NEW JERSEY, CONNECTICUT, INTERSTATE REGION AND THE HUDSON VALLEY INTRASTATE REGION

TABLE 2-4

POLLUTANT LEVELS FOR DETERMINING AIR QUALITY CONTROL REGION CLASSIFICATIONS

POLLUTANT	CLASS OF REGION I	 II	 III
Sulfur oxides			
Annual arithmetic mean	> 100 μg/m³	60-100 μg/m³	< 60 μg/m³
24-hour maximum	> 455 μg/m³	260-455 μg/m³	< 260 μg/m³
3-hour maximum	--	≥ 1300 μg/m³	< 1300 μg/m³
Particulate matter			
Annual geometric mean	> 95 μg/m³	60-95 μg/m³	< 60 μg/m³
24-hour maximum	> 325 μg/m³	150-325 μg/m³	< 150 μg/m³
Carbon monoxide			
1-hour maximum	> 55 mg/m³	--	< 55 mg/m³
8-hour maximum	≥ 14 mg/m³	--	< 14 mg/m³
Nitrogen dioxide			
Annual arithmetic mean	≥ 110 μg/m³	--	< 110 μg/m³
Photochemical oxidants			
1-hour maximum	≥ 195 μg/m³	--	< 195 μg/m³

μg/m³ = micrograms per cubic meter; mg/m³ = milligrams per meter.

Source: 40 CFR 51.3.

II for nitrogen oxides, carbon monoxide and photochemical oxidants (U.S. Environmental Protection Agency, 1974). It may be well to note that the above classification system is based on data recorded at monitoring stations and, therefore, is limited in its representation of air quality within the entire region. Ambient concentrations of pollutants could be above or below those implied by the classification in isolated localities in the region.

2.46 In addition to the designation of Air Quality Control Regions, Federal regulations provide for the delineations of Air Quality Maintenance Areas (AQMAs) or areas within which violations of Federal ambient air quality standards can be expected over the decade between 1974 and 1984. The Hudson River estuary overlaps three such areas--the New York-New Jersey-Connecticut (coextensive with the Air Quality Control Region), the Mid-Hudson (extending up the valley to encompass Greene and Columbia Counties) and the Capital District (the northern end of the study area) Air Quality Maintenance Areas.

2.47 The State of New York has promulgated standards applicable to ambient air quality over the State, in accordance with provisions of the Clean Air Act. A summary of these standards together with Federal Ambient air quality standards (40 CFR 50) is given in Table 2-5. An extensive network of continuous and manual air quality monitoring systems is maintained throughout the state by the Department of Environmental Conservation, Bureau of Air Quality Surveillance (New York State Department of Environmental Conservation, 1976). In addition, monitoring systems in the New York City area and on Long Island are maintained, respectively, by the New York City Department of Air Resources and the Long Island Lighting Company (New York State Department of Environmental Conservation, 1976).

2.48 Air quality through the State of New York continues to show general improvement (New York State Department of Environmental Conservation, 1976). Since 1970, there has been a fairly consistent reduction in sulfur dioxide levels at most continuous air monitoring stations, with, for the first time in 1975, no station recording any excesses over ambient standards for sulfur dioxide. Substantial declines in annual average values of sulfur dioxide concentrations have been noted at several continuous monitoring stations in the state, a number of them within or near the study area. Among these, the Roosevelt Island Monitor in the New York city area has shown the largest decline in the state--a reduction of 73 percent between 1970 and 1975. Lesser reductions have been measured at Kingston (55 percent), Rensselaer (30 percent) and Eisenhower Park on Long Island (40 percent). The running annual averages of sulfur dioxide concentrations shown in Figure 2-9 illustrate the declining trends in measured concentrations where these have been most pronounced in the State of New York.

TABLE 2-5

SUMMARY OF SELECTED NEW YORK STATE AND FEDERAL AMBIENT AIR QUALITY STANDARDS

CONTAMINANT[1]	PARAMETER		NEW YORK STANDARDS[2]			FEDERAL PRIMARY STANDARDS		FEDERAL SECONDARY STANDARDS	
	AVERAGING PERIOD	STATISTIC	(ppm)	($\mu g/m^3$)	LEVEL	(ppm)	($\mu g/m^3$)	(ppm)	($\mu g/m^3$)
Sulfur Dioxide	12 consecutive months	Arithmetic mean of 24-hour average concentrations	0.03	80	All	0.03	80		
	24 hours[3]	Maximum[4]	0.14	365	All	0.14	365		
	3 hours[5]	Maximum	0.5	1,300	All			0.5	1,300
Total Suspended Particulates	12 consecutive months	Geometric mean of 24-hour average concentrations		45	I		75		60
				55	II				
				65	III				
				75	III				
	24 hours	Maximum		250	All		260		150
	30 days[6]	Arithmetic mean of 24-hour average concentrations		80	I				
				100	II				
				115	III				
				135	IV				
	60 days[6]	Arithmetic mean of 24-hour average concentrations		70	I				
				85	II				
				95	III				
				115	IV				
	90 days[6]	Arithmetic mean of 24-hour average concentrations		65	I				
				80	II				
				90	III				
				105	IV				
Nitrogen Dioxide	12 consecutive months	Arithmetic mean of 24-hour average concentrations	0.05	100	All	0.05	100	0.05	100

ppm = parts per million by volume; $\mu g/m^3$ - micrograms per cubic meter

[1] New York State also has standards for carbon monoxide, photochemical oxidants, hydrocarbons (nonmethane), beryllium, fluorides, hydrogen suflide and settleable particulates (dustfall). Standards apply at a reference temperature of 25°C and reference pressure of 760 millimeters of mercury.

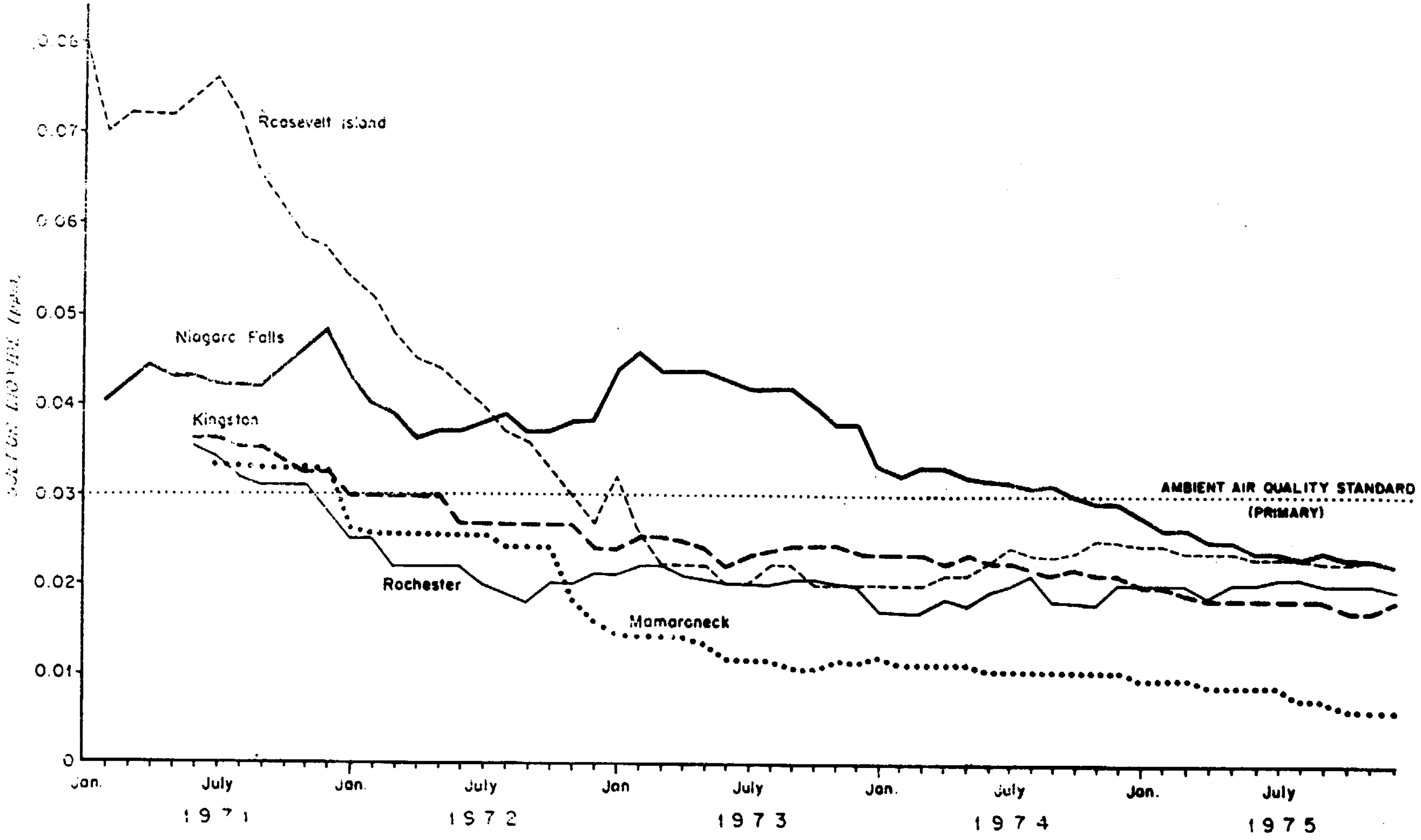
[2] In effect March 1977.

[3] Also during any 12 consecutive months. 99 percent of the values are not to exceed 0.10 ppm in New York State.

[4] All maximum values are values not to be exceeded more than once a year.

[5] Also during any 12 consecutive months, 99 percent of the values are not to exceed 0.25 ppm in New York State.

[6] For enforcement only.



Source: New York State Air Quality Report, 1976.

FIGURE 2-9

RUNNING ANNUAL AVERAGES OF SULFUR DIOXIDE TRENDS FOR 1971 THROUGH 1975

2.49 Readings of sulfur dioxide concentrations from the manual monitoring stations throughout the state generally corroborate the findings of the continuous monitoring stations (New York State Department of Environmental Conservation, 1976). The annual arithmetic means of sulfur dioxide concentrations reported by manual monitoring stations within the study area (excluding New York City and the New Jersey counties) for the years 1973, 1974 and 1975 are given in Table 2-6. None of the reported measurements in 1975 exceeds the Federal and state ambient air quality standards of 0.03 parts per million, annual arithmetic means. Relatively high values are reported in the Albany area, Kingston, Poughkeepsie and the coastal and southern portions of Westchester County. Stations in Rockland County show some of the lowest values recorded in the study area.

2.50 Observations of total suspended particulate concentrations recorded in 1973, 1974, and 1975 at manual monitoring stations within the study area (excluding New York City and the New Jersey counties) are shown in Table 2-7. The data indicate a generally improving or stable situation, with all stations except two in the Albany area reporting annual geometric mean concentrations below the Federal and state standards of 75 micrograms per cubic meter. While the information presented in Table 2-7 is inadequate to establish statistically significant trends, it may be noted that only 7 of the 43 sites reporting fail to show monotonically decreasing values from 1973 to 1975.

2.51 Fragmentary field data on airborne contaminants other than sulfur dioxide and total suspended particulates have been collected (New York Department of Environmental Conservation, 1976). Where analysis of the available data is possible (New York Department of Environmental Conservation, 1976), there are no indications that air quality is deteriorating in the study area. Instances of violations of Federal and state ambient air quality standards are generally less frequent in the data reported in 1975 than in previous years.

TABLE 2-6

ANNUAL ARITHMETIC MEAN CONCENTRATIONS OF SULFUR DIOXIDE IN THE STUDY AREA FOR 1973 THROUGH 1975 (ppm)

STATION (STATION NO.)	1973	1974	1975
Albany County			
Albany (03)	0.021	0.018	0.017
Albany (08)	0.030	0.033	
Albany (13)			0.021
Cohoes (01)		0.014	0.011
Rensselaer County			
Troy (02)		0.008	0.007
Greene County		NO DATA AVAILABLE	
Columbia County			
Hudson (02)		0.006	0.006
Philmont (02)		0.006	0.006
Ulster County			
Kingston (09)			0.011
Dutchess County			
Poughkeepsie (04)		0.012	0.017
Fishkill (01)			0.009
La Grange (01)		0.009	0.007
Orange County		NO DATA AVAILABLE	
Putnam County		NO DATA AVAILABLE	
Rockland County			
West Haverstraw (01)	0.005	0.007	0.006
Nyack (04)	0.007	0.008	0.006
Clarkstown (03)	0.002	0.005	0.003
Westchester County			
White Plains (01)	0.011	0.014	0.012
Mount Vernon (04)		0.016	0.016
Port Chester (02)	0.010	0.011	0.012
Mamaroneck (01)	0.012	0.014	0.013
Greenburg (01)	0.010	0.009	0.007
Mount Pleasant (02)	0.008	0.010	0.008
Somers (02)	0.006	0.007	0.008

Both Federal and state ambient air quality standards are 0.03 parts per million, annual arithmetic mean.

Source: New York State Department of Environmental Conservation, 1976.

TABLE 2-7

ANNUAL GEOMETRIC MEAN CONCENTRATIONS OF TOTAL SUSPENDED PARTICULATE IN THE STUDY AREA FOR 1973 THROUGH 1975 ($\mu g/m^3$)

STATION (STATION NO.)	1973	1974	1975
Albany County			
Albany (02)	110	95	79
Albany (03)	57	51	50
Albany (10)	102	76	75
Albany (13)	93	69	66
Coeymans (01)	61	44	41
Coeymans (02)	53	52	42
Colonie (03)	55	51	52
Rensselaer County			
Rensselaer (02)	74	62	54
Troy (02)	55	53	46
Castleton (01)	34	39	39
Grafton (01)	30	28	30
Greene County			
Catskill (02)	107	101	64
Columbia County			
Hudson (02)	56	58	47
Philmont (02)	29	28	29
Germantown (01)	51	46	39
Ulster County			
Kingston (04)	69	79	56
New Paltz (01)	57	61	48
Ellenville (02)	41	43	32
Saugerties (01)	70	46	43
Shawangunk (02)	50	40	31
Dutchess County			
Poughkeepsie (04)	48	58	56
Rhinebeck (02)	46	41	40
La Grange (01)	37	34	30
Orange County			
Newburgh (02)	84	73	65
Putnam County			
Brewster (01)	51	49	41
Rockland County			
West Haverstraw (01)	47	49	48
Suffern (06)	56	53	48
Clarkstown (01)	50	44	37
Orangeburg (01)	54	52	46
Westchester County			
Peekskill (01)	65	76	60
White Plains (01)	57	55	50
Mt. Vernon (04)	71	54	50
New Rochelle (02)	64	58	59
Ossining (01)	44	59	46
Port Chester (02)	51	57	42
Rye (01)	58	59	64
Mamaroneck (V) (01)	51	50	48
North Tarrytown (01)	46	53	44
Greenburgh	59	61	55
Mamaroneck (T) (01)	60	59	52
Mt. Pleasant (02)	40	45	42
Somers (02)	36	36	34
Yorktown (02)	32	37	33

Both Federal and state ambient air quality standards are 75 micrograms per meter, annual geometric mean.

Source: New York State Department of Environmental Conservation, 1976.

BIOLOGICAL RESOURCES

2.52 The biological resources of the Hudson River valley are extensive and varied. Terrestrial ecosystems include upland forests, old-field and second growth communities, agricultural lands, and suburban and urban environments. Both freshwater and marine wetland communities are found. Aquatic ecosystems include marine ecosystems at the mouth of the river near New York, medium and low-salinity ecosystems in the lower and middle estuary, and freshwater ecosystems in the upper estuary.

Upland Ecosystems

2.53 The Hudson River Valley south of Troy, New York, lies within the Oak-Chestnut Forest Region (Braun, 1950; Shelford, 1963). The chestnut has gradually disappeared with the spread of the chestnut blight and has been replaced by several species of oaks and hickories.

2.54 Because the Hudson River Valley has been extensively utilized by man for almost three centuries, past and present land use largely determines the type of vegetation that now exists. Nearly all of the forest land has been cut more than once. Since the peak of agricultural activities in the 1880s, much land has reverted to forest through natural succession. Because of the mixture of second growth forest, agricultural, and open land, the predominant animals are white tailed deer, rabbits, skunks, opossum, raccoons, squirrels, red and gray fox and ruffled grouse that adapt to this type of habitat.

2.55 Observations of the upland vegetation of the Bowline Point area prior to construction of the Bowline Generating Station are sketchy. At the time of a site visit in November 1976, willows were observed to be one of the dominant trees, with black ash, elm, and red maple also common. Animals of the area have not been surveyed. Communities in the area are likely to be made up of those species typically associated with the mixture of urban land, old field communities, tidal and nontidal wetlands, and second growth woodlands that exist.

Wetland Ecosystems

2.56 The tidal wetlands of the Hudson River Valley south of Troy consist of freshwater marshes in the northern portion and marshes adapted to the conditions of moderate salinity in the southern portion. Freshwater tidal marshlands found north of Mile Point 60 to 65 typically have higher diversity of fish species and are important nesting, resting and feeding areas for migrating waterfowl (Kiviat, 1973). Similarly, moderate salinity wetlands are known to be highly productive and to support a very diverse fauna of fish, invertebrates, and seasonally migrating waterfowl.

2.57 The abundance of some plants found in six tidal wetlands of the oligohaline Haverstraw Bay vicinity (Figure 2-10) surveyed in 1972 are compared in Table 2-8 (Lawler, Matusky and Skelly, 1975). Description of the marshes in the vicinity of the Bowline Point (Figure 2-11 and Table 2-9) prior to the construction of the power plant (Foley and Tabor, 1951; New York State Conservation Department, 1972) indicates that these marshes are similar to other marshes in the Haverstraw Bay area.

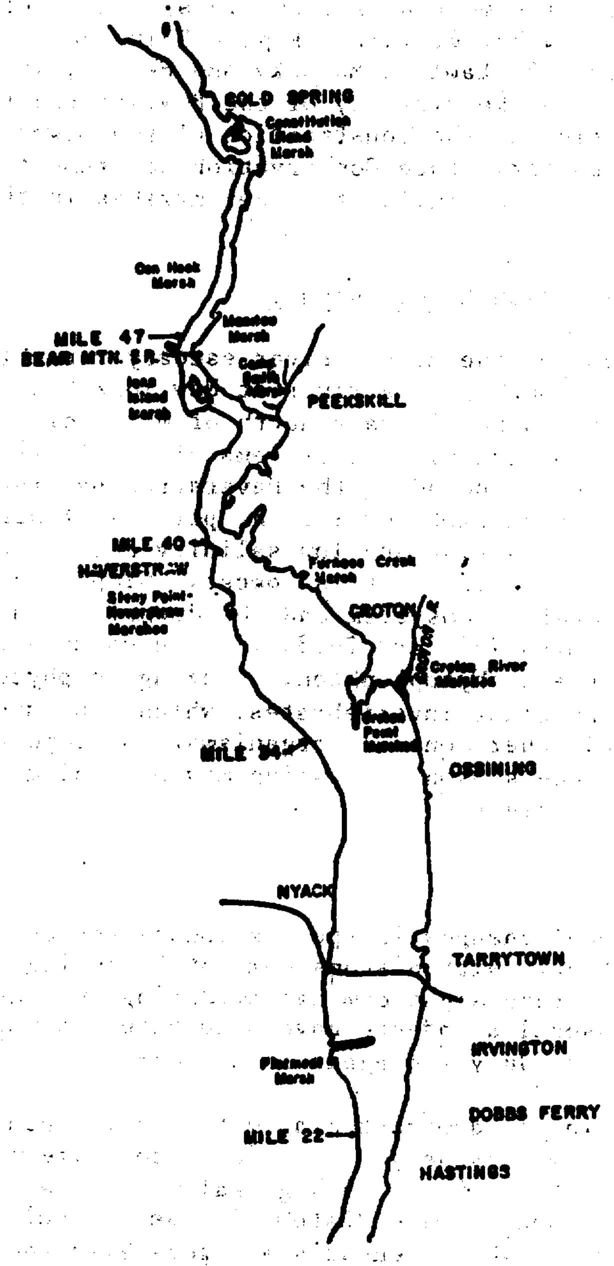
Aquatic Ecosystems of the Hudson River Estuary

2.58 The ecosystems of the Hudson River estuary range from high salinity areas at the mouth of the river at New York City to the freshwater ecosystems of the upper estuary north of Mile Point 65. In between are the mid to low-salinity ecosystems of the lower estuary and the oligohaline areas, including the Haverstraw Bay region, that experience freshwater conditions during the periods of high freshwater flow in winter and spring and low salinity conditions during summer and fall when freshwater flow is lowest. Simplified diagrams of the upriver freshwater ecosystem and the downriver saline ecosystem are given in Figures 2-12 and 2-13. In the estuary the dominant primary producers are phytoplankton. Grazing on phytoplankton are the zooplankton and other invertebrates, which, in turn, serve as food for fish and other consumer organisms. An important feature of the estuary is the seasonal spawning movement of many fish species into and out of the river.

Phytoplankton

2.59 Strong seasonal changes in species compositon occur throughout the Hudson estuary, with diatoms dominating during colder months and green and blue-green algae dominating during the warmest months. Two peaks of seasonal abundance have been noted in many studies, usually in April to July and again in October to December.

2.60 Differences in the dominant diatom type have been observed in the mid- and lower estuary. Centric diatoms are most abundant near the mouth of the estuary in high salinity areas. Dominance is shared by centric and pennate diatoms in the mid-salinity reaches of the lower estuary, while pennates are generally the most abundant in the oligohaline portions of the middle estuary, including the Bowline Point area. Because salinity tolerance varies among phytoplankton species, community dominance changes at Bowline Point seasonally with salinity.



Source: Lawler, Matusky and Skelly, June 1975.

FIGURE 2-10

TIDAL MARSHES OF THE HUDSON RIVER FROM HASTINGS TO COLD SPRING, NEW YORK

TABLE 2-8
RELATIVE ABUNDANCE IN 1972 OF SOME PLANTS IN SIX MARSHES ALONG THE HUDSON RIVER

SPECIES	PIERMONT	CROTON	HAVERSTRAW	IONA	MANITOU	CONSTITUTION
MONOCOTYLEDONS						
Gramineae (Grasses)						
Phragmites communis	xxx	xx	xx	xx	x	xx
Spartina alterniflora	xxx	xx	x	-	-	-
S. cynosuroides	xxx	x	x	-	-	-
S. patens	xxx	xx	-	-	-	-
S. pectinata	x	-	x	-	-	-
Distichlis spicata	xxx	xx	-	-	-	-
Zizania aquatica	-	x	xx	x	-	xxx
Echinochloa walteri	?	xx	xx	xx	?	xx
Leersia oryzoides	?	xx	xx	-	-	-
Cyperaceae (Sedges)						
Scirpus robustus	xx	x	-	-	-	-
S. americanus	xx	xx	xx	x	x	x
S. fluviatilis	xx	x	x	-	-	-
S. olneyi	x	xx	x	xxx	xx	xx
S. validus	xx	x	x	x	-	xx
Cyperus odoratus	?	xx	xx	?	?	?
Eleocharis calva	?	xx	?	?	?	?
Juncaceae (Rushes)						
Juncus gerardi	xx	x?	-	-	-	-
Other Monocots						
Typha augustifolia	xxx	xxx	xxx	xxx	xxx	xxx
T. latifolia	x	-	x	x	xx	x
Eleocharis parvula	?	xx	?	?	-	-
Peltandra virginica	xx	xx	xxx	xxx	xxx	xxx
Pontederia cordata	?	x	x	xx	?	xx-xxx
DICOTYLEDONS						
Broadleaf						
Lilaeopsis lineata	xx	xx	?	?	?	?
Iva frutescens	xx	-	-	-	-	-
Solidago sempervirens	x-xx	-	-	-	-	-
Atriplex patula	x	x?	-	-	-	-
Ptilimnium capillaceum	x	xx	-	-	-	-
Lythrum salicaria	xx	xx	xx	xx	xx	xx
Rosa palustris	?	x	x	x	x	xx
Cornus amomum	?	x	x	x	x	xx
Hibiscus palustris	xx	xx	x	x	?	xx
Impatiens biflora-capensis	x	x	xx	xx	x	xx
Cephalanthus occidentalis	-	x	x	x	x	x
Rhus vernix	-	-	-	xx	x	-
Pluchea purpurascens	xx	xx	x	?	-	xx
Polygonum arifolium	x	?	xx	xx	x	xx
P. punctatum	xx	xx	xx	xx	-	xx
PTERIDOPHYTES (Ferns)						
Thelypteris palustris	xx	x	xx	xxx	xxx	xxx
Onoclea sensibilis	?	x	xx	xx	xx	xx
Osmundus regalis	?	-	x	xx	xx	xx

Key:
x = incidental
xx = occasional to common
xxx = very common or large clones
\- = not present
? = questionable identification

Source: Lawler, Matusky and Skelly, June 1975.

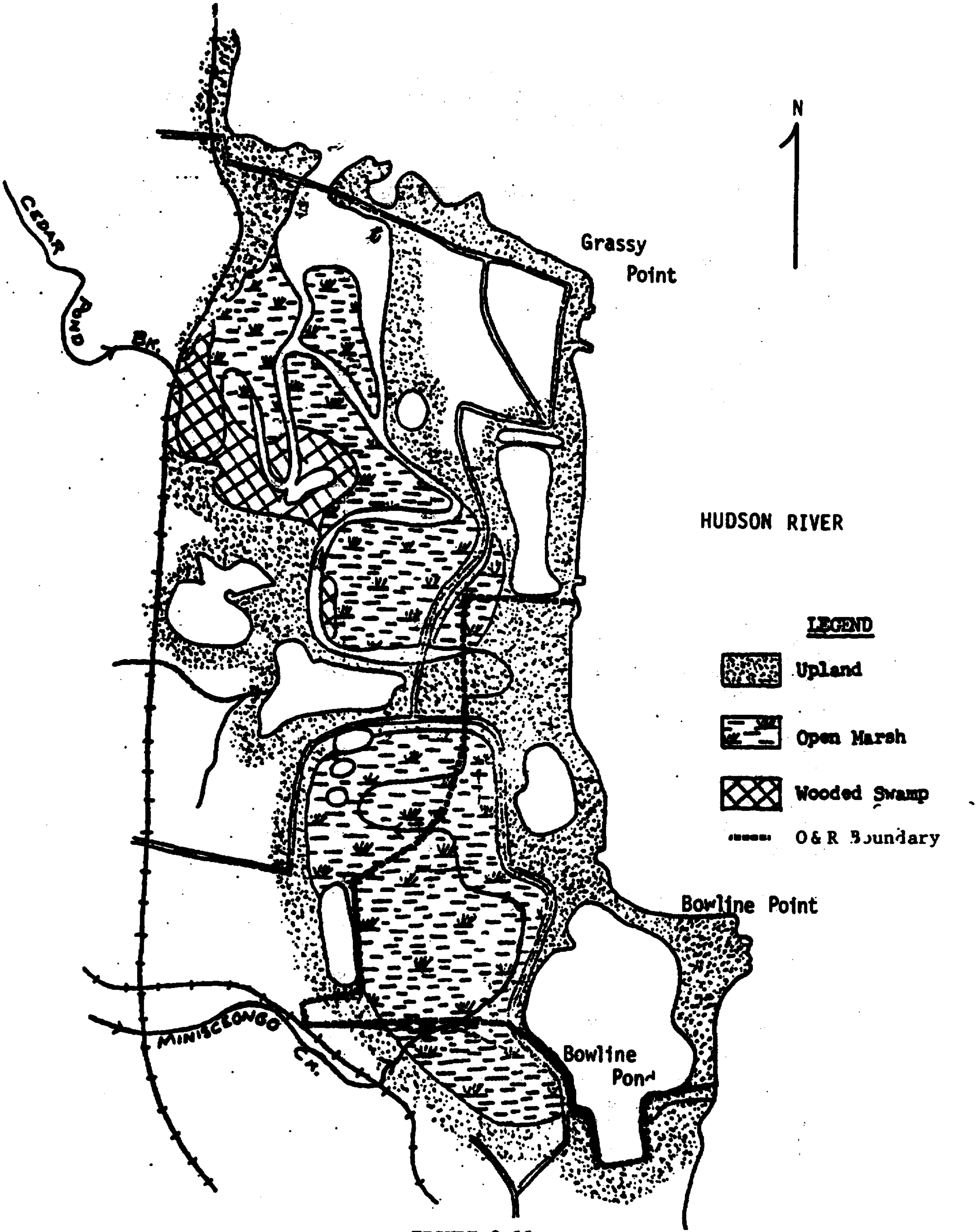


FIGURE 2-11

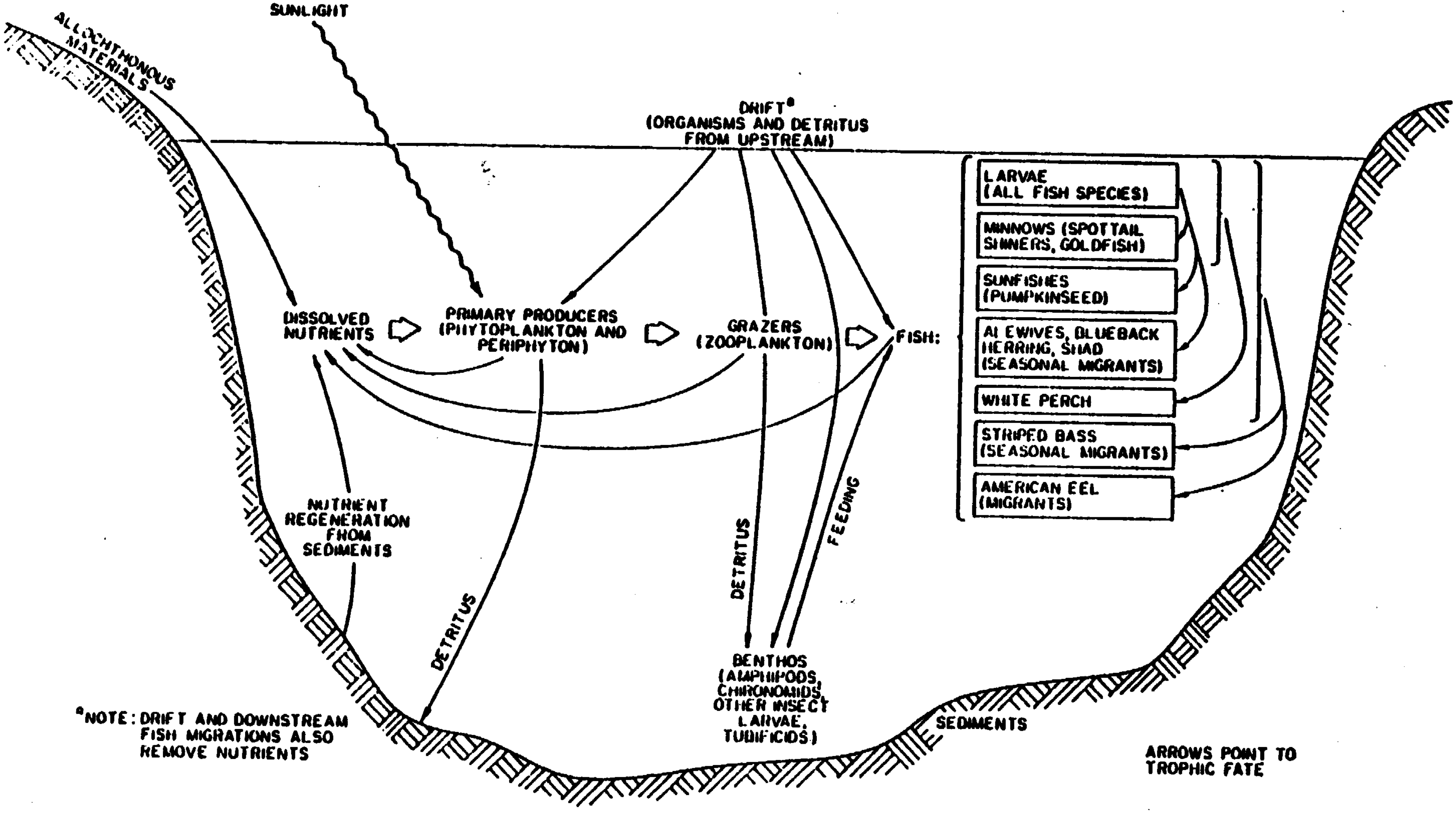
HABITAT MAP OF GRASSY POINT MARSH
BEFORE CONSTRUCTION OF THE BOWLINE GENERATING STATION

TABLE 2-9

VEGETATION OF THE GRASSY POINT MARSH

AREA STUDIED	VEGETATION	ABUNDANT	COMMON	UNCOMMON
North End of Present Property	Arrow arum			x
	Common cattail	x		
	Narrow-leaved cattail		x	
	Sweet flag		x	
	Water hemp			x
	Common jewelweed		x	
	Purple loosestrife	x		
	Swamp mallow			x
	Water parsnip			x
	Pickerelweed			x
	Common duck potato			x
	Wild rice			x
	Swamp smartweed		x	
Open Marsh Under Present Site	Common cattail	x		
	Reed grass		x	
	Common jewelweed			x
	Purple loosestrife	x		
Edge of Bowline Pond - NE	Wild celery	x		
	Sago pondweed		x	
	Common waterweed		x	
	Reed grass		x	
	Common jewelweed		x	
Edge of Bowline Pond (west)	Common coontail		x	
	Lesser bushy pondweed	x		
	Sago pondweed	x		

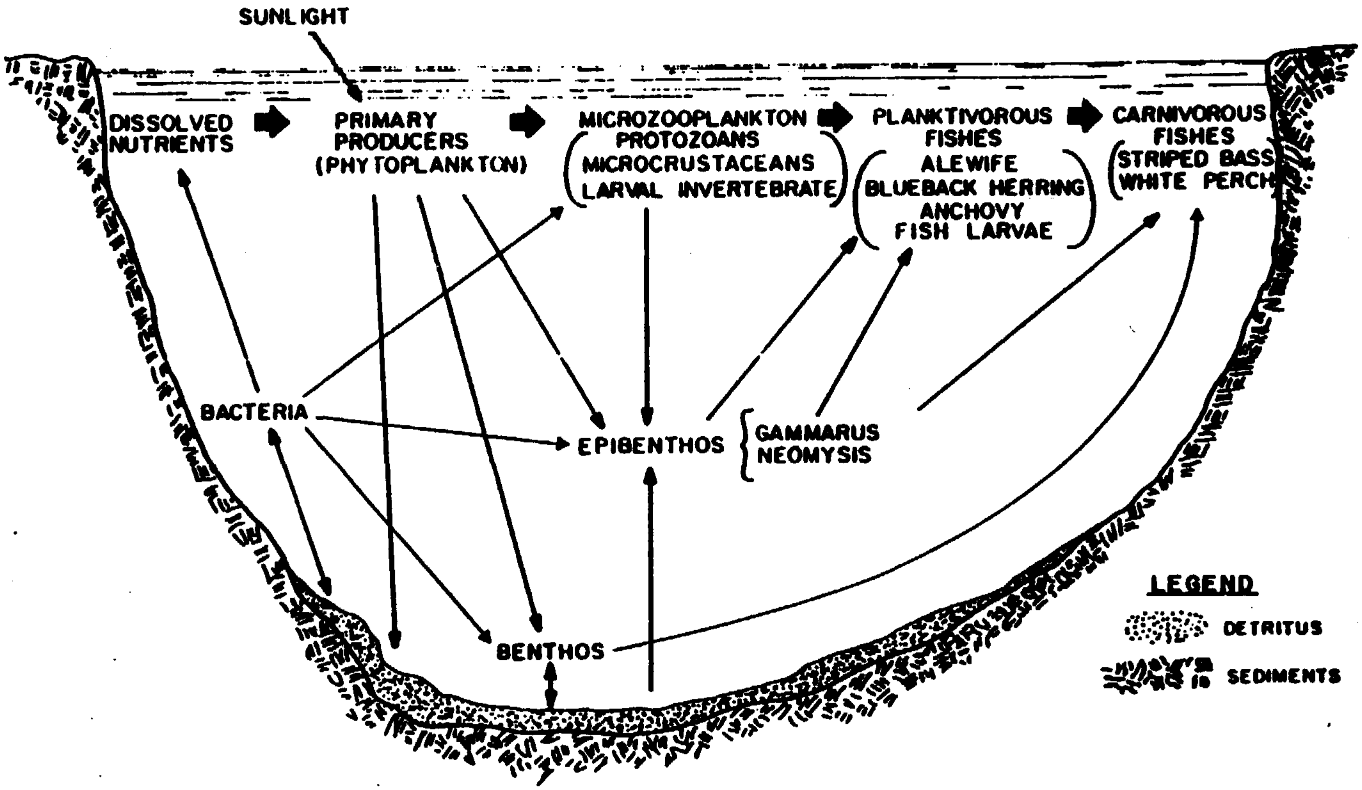
Source: Foley and Taber, 1951.



Source: U.S. Nuclear Regulatory Commission, 1976

FIGURE 2-12

SIMPLIFIED TROPHIC MODEL FOR THE HUDSON RIVER AT THE PROPOSED GREENE COUNTY NUCLEAR POWER PLANT SITE



Source: Modified from U.S. Atomic Energy Commission, 1972.

FIGURE 2-13

SIMPLIFIED AQUATIC FOOD WEB NEAR BOWLINE POINT

2.61 Total phytoplankton abundance tends to increase upstream from the mouth of the estuary. The largest standing stock of phytoplankton (measured as chlorophyll a and c) often occurs between the George Washington Bridge and Ossining during the spring-summer pulse of abundance.

Zooplankton

2.62 The zooplankton community in the Hudson River estuary is divided into the microzooplankton such as copepods, protozoans and rotifers, and the macrozooplankton such as amphipods and isopods. The community includes those species such as copepods that live their entire life cycle as plankton (holoplankton) and the planktonic larval forms of species (primarily benthic organisms) whose adult form is nonplanktonic (meroplankton).

2.63 Distribution of species along the length of the estuary varies with salinity. Mixtures of marine and salinity-tolerant freshwater species are common in the saline and brackish water portions of the estuary. Marine or brackish water organisms are rare in the freshwater portions of the estuary. A few species such as the amphipod *Gammarus* are common in all parts of the estuary.

2.64 Copepods are generally the dominant zooplankton species in the low salinity portions of the estuary, with cyclopoid forms most numerous in the winter and and calanoid forms in the summer. In the freshwater portions of the estuary, limited data suggest that Cladacerans (especially the Leptodoridae) are dominant during the summer months and copepods during the winter and spring. Rotifers are moderately abundant and may at times become numerically dominant over copepods (exclusive of copepod nauplii).

2.65 Zooplankton are most abundant during the late spring and summer in the low salinity portion of the estuary. Sometimes a smaller fall maximum will occur. Data for one year from the estuary north of Saugerties suggests that the same pattern may occur in the freshwater portion of the estuary also.

2.66 Zooplankton in the estuary tend to exhibit daily vertical migration, being most abundant in deep water during the day. Surface abundance increases greatly at night. Vertical migration is less evident among microzooplankton forms.

Benthic Animals

2.67 The salinity gradient within the Hudson River estuary is important in determining the composition of the benthic community at any point within the estuary (Ristich et al., 1977). Marine organisms adapted to relatively stable salinity conditions are restricted to a narrow portion of the estuary near the mouth. Freshwater species gradually disappear as the salinity increases downstream in the estuary. The oligohaline zone exhibits the lowest species diversity because of the rapid changes in salinity experienced as freshwater flow increases and decreases in response to seasonal rainfall patterns.

2.68 Organisms are most abundant in summer and early fall when reproduction has occurred. Biomass is greatest in fall after some growth of smaller individuals has occurred.

2.69 In the midsalinity zone, benthic community structure was initially thought to be constant from year to year (Lawler, Matusky and Skelly, 1975a). However, recent studies have shown the yearly as well as seasonal variation expected to occur in normal benthic communities (Orange and Rockland, 1977). The isopod Cyathura polita is widespread, indicating low levels of pollution. Organisms characteristic of higher salinities become more prevalent in late summer and early fall when freshwater flow is lowest. The dominant organisms are annelid worms with oligochaetes more prevalent in lower salinities upstream and polychaetes more abundant toward the estuary mouth. However, at times the gastropod Amnicola becomes dominant in the benthic community (Orange and Rockland, 1977). Benthic organisms are used by many species of fish as a food resource, depending on the fish species, size, and time of year. The amphipod Gammarus, various copepods, and dipterans are known to constitute a substantial portion of the food resource used by Hudson River fishes (Orange and Rockland, 1977).

2.70 The benthic community of the oligohaline zone has been studied most extensively in the Newburgh Bay area. Dominant benthic organisms were oligochaete worms and dipterans (insects). Numbers are greatest in spring and least in fall, except for dipterans, which are most abundant in winter and least abundant during spring. Community structure has been similar over the years studied, with year-to-year similarity greatest during spring and least during fall. The major fish food is the amphipod, Gammarus.

2.71 In the freshwater zone, oligochaetes and dipterans are the dominant forms. Biomass patterns are seasonal and generally related to various life cycles.

2.72 Many studies have shown the importance of benthic organisms in the diet of fish. McFadden (1977) reported that juvenile fish in the Hudson River prey upon copepods, cladocerans, amphipods, insect larvae, polychaetes, mysids, crabs, and ostracods. Adult fish consume amphipods, insect larvae, isopods, polychaetes, copepods, chironomid larvae, and shrimp. The use of food resources by fish varies with season and availability of particular food items.

Fish Eggs, Larvae, and Adults

2.73 The major migratory fish utilizing the Hudson River estuary are the striped bass (*Morone saxatilis*), American shad (*Alosa sapidissima*), blueback herring (*Alosa aestivalis*), Atlantic tomcod (*Microgradus tomcod*), alewife (*Alosa pseudoharengus*), ~~and American~~ eel (*Anguilla rostrata*). White perch (*Morone americana*) is an important resident species with seasonal movements in the estuary. Except for the eel, these species utilize the estuary for spawning and as a nursery area for their young. The migratory species usually spend their adult life in the downstream, high-salinity portions of the estuary or in the offshore coastal waters, moving into the middle and upper estuary to spawn. Summary life histories of the major migratory fishes of the Hudson River are given in Appendix D.

not migratory

~~tomcod~~

2.74 Information on the general spawning periods of several species and their general spawning zones is summarized in Figures 2-14 and 2-15. Although not listed in the figures, bay anchovy is an important species spawning in the mid-salinity areas of the lower estuary as well as saline waters along the Atlantic coast (Orange and Rockland, 1977). Most species are spring and summer spawners and utilize the freshwater portion of the estuary.

2.75 Yolk sac and post-yolk sac larval stages of these species move downstream at variable rates into the oligohaline zone of the salt front. As growth continues and the juveniles obtain mobility against the currents, the downstream movement continues and several species (especially striped bass) exhibit strong movement to shallow and shoal areas.

2.76 By late fall most young and adults have moved to the lower estuary. Many adults move into the Atlantic coastal waters during the winter. Young striped bass and some adults may overwinter in the lower Hudson River estuary.

Fishery Resources

2.77 The commercial fishery in the Hudson River estuary is generally confined to the lower river between Tappan Zee and Croton-Haverstraw Bay (about Mile Points 25 to 40). Some commercial fishing also takes place in the upper river from about Mile Point 70 to 120, where the primary species of value are the American shad and striped bass. The lower river fishery is primarily for shad, but striped bass, Atlantic sturgeon, white perch, and Atlantic tomcod are also

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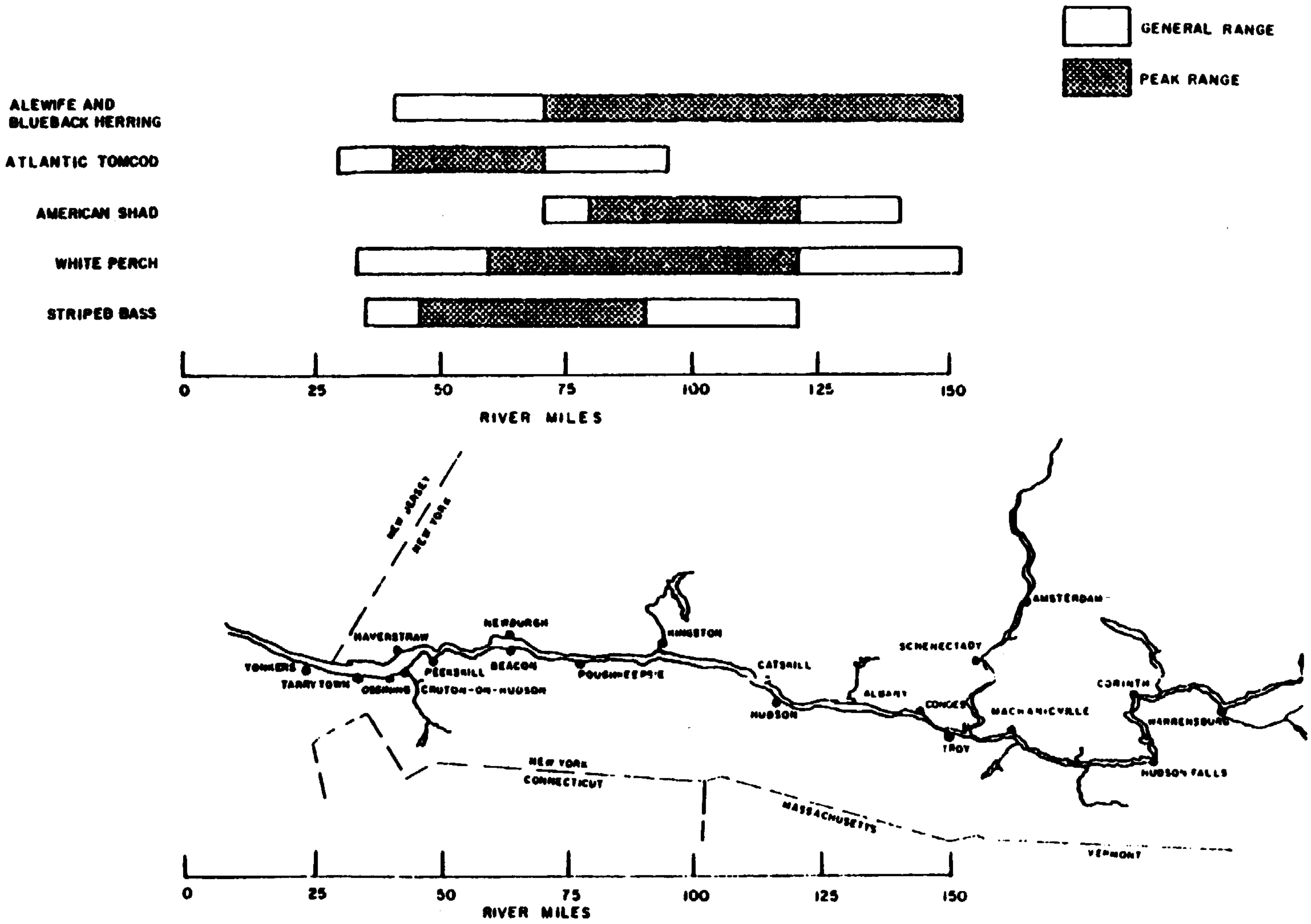
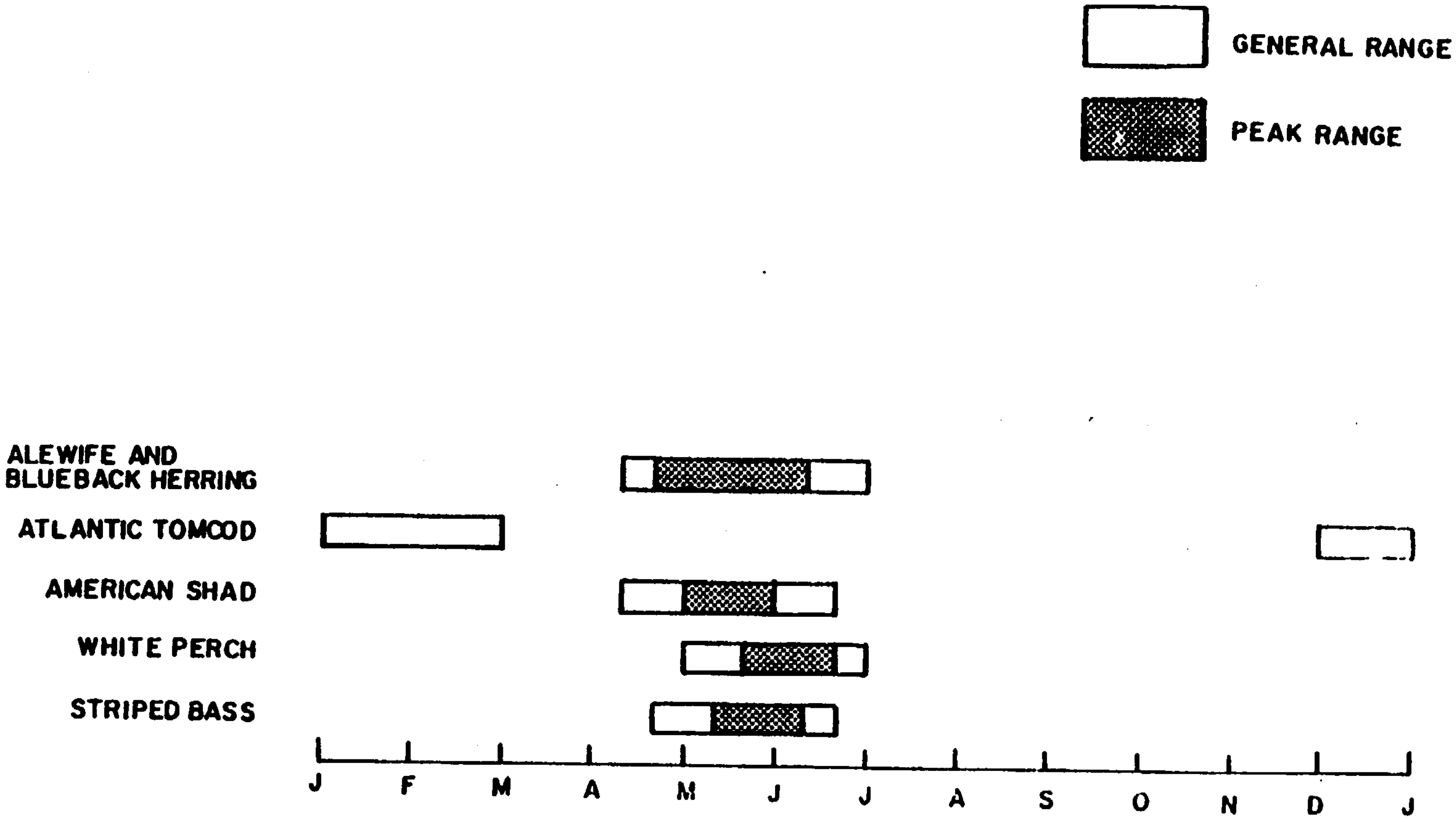


Source: Texas Instruments, 1975

Any more Recent charts?

FIGURE 2-14

GENERALIZED DESCRIPTION OF SPAWNING GROUNDS OF ANADROMOUS FISH IN THE HUDSON RIVER ESTUARY



Source: Texas Instruments, 1975

FIGURE 2-15

GENERALIZED DESCRIPTION OF TEMPORAL SPAWNING DISTRIBUTION OF MAJOR ANADROMOUS FISH SPECIES collected. The fishing season is confined to the spring during the adult spawning runs.

2.78 Displayed in Figures 2-16 and 2-17 are historical trends through 1975 of Hudson River commercial landings of shad, striped bass, and alewives. While the landing statistics may vary with the intensity of fishing effort and lack precise location of capture, they provide long-term historical records.

2.79 Sport fishing is also an important use of the Hudson River's fishery resource. In 1970, the weight of the sport catch in the North Atlantic region (including New York) was 45,844,000 pounds (Deuel, 1973), compared to the commercial catch in the New England Region plus New York State of 2,780,000 pounds (U.S. Department of Commerce, 1971). However, only a portion of the North Atlantic stock is dependent on the Hudson River for spawning and nursery grounds. Striped bass spawned in the Hudson River appear to make a substantial contribution (up to 30 percent) to the fishing stocks in the North Atlantic (see Table 4-34), although presently the bulk of striped bass appear to originate in the Chesapeake Bay.

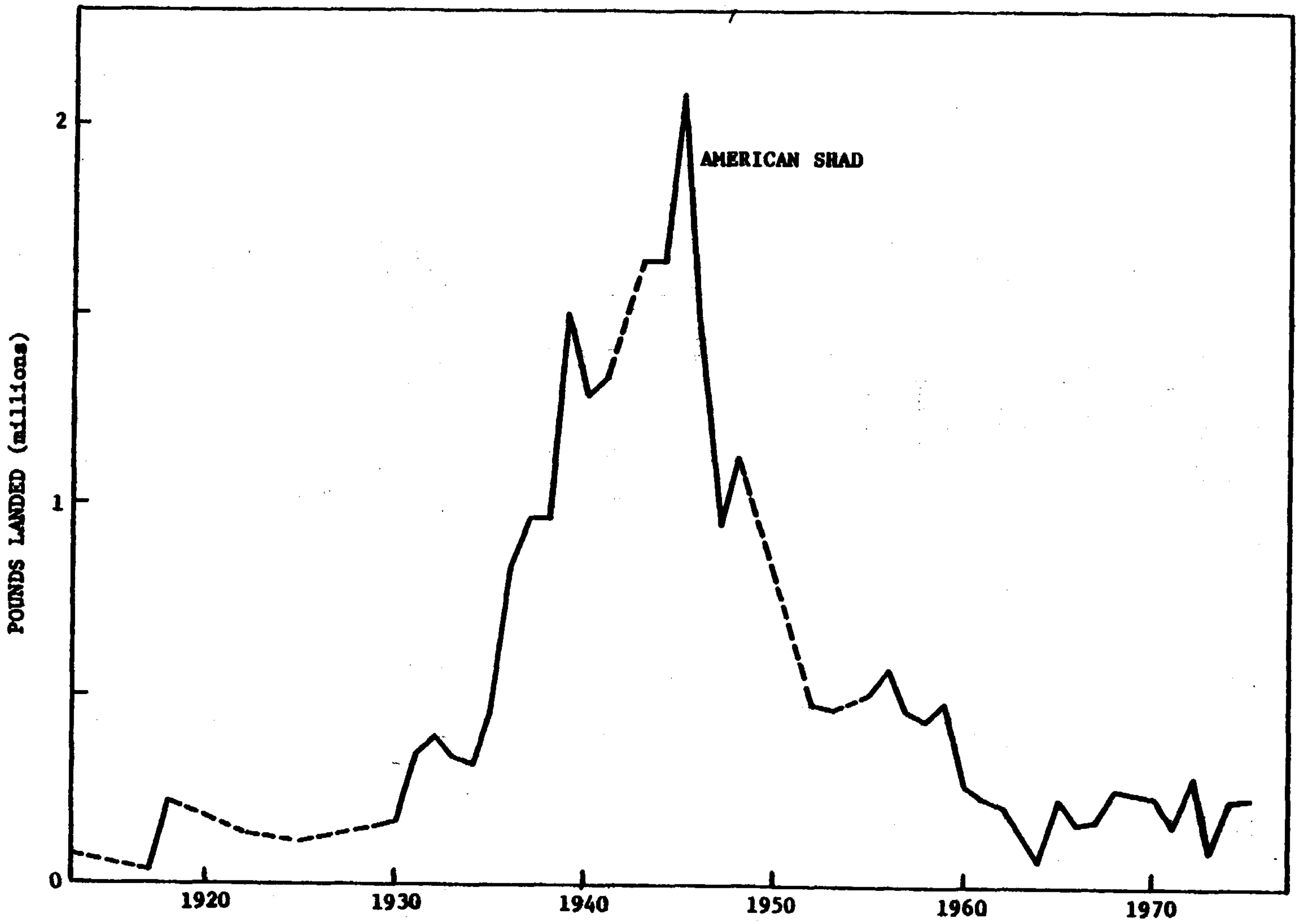
greater than what we estimate

Endangered or Threatened Species

2.80 Protected animals that are resident, extirpated, or extinct in New York State are listed in Table 2-10. In addition, all species of wildlife and plants listed by the U.S. Department of the Interior, Fish and Wildlife Service as threatened or endangered (41 FR 43340) are also considered as threatened or endangered in New York State (NYCRR Section 182.1, Title 6). However, most of these species are not indigenous to the state.

Are not Atlantics fished commercially?

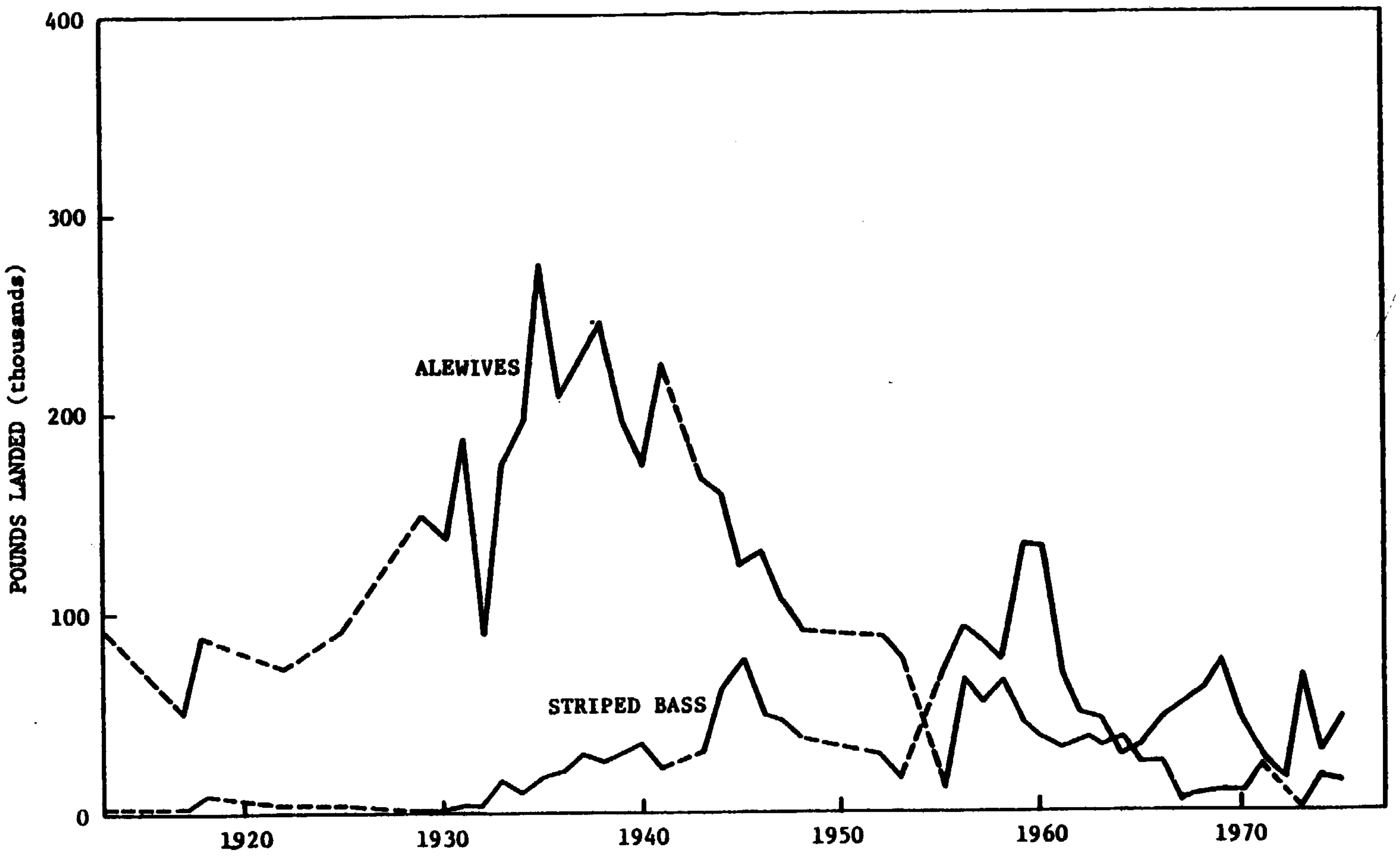
2.81 Two endangered or threatened species that potentially could be most affected by power plant operations are the shortnose and Atlantic sturgeons. Most Atlantic sturgeon present in the Hudson River during December through March are immature fish congregating in obstacle-strewn deep areas, primarily between Pollepel Island (RM57) and George Washington Bridge (RM12) (Figure 2-2). In spring, immature fish move up the river and have been observed as far north as Esopus Meadows (RM87). During summer, the immature sturgeon seek cooler, deeper waters. The distribution of juvenile Atlantic sturgeon is largely dependent on water salinity and temperature (Dovel, 1979). Spawning adults occur in the estuary from April through October. Spawning males are at least 12 years of age, weighing 12 to 105 pounds. The youngest mature female collected to date was 18 years old and weighed 72 pounds (including 8 pounds of ripe eggs). Atlantic sturgeon spawn roughly between RM36 and RM83 (see Figure 2-2), following the seasonal movement of the salt front upstream from May through July. Larvae, post yolk-sac larvae, and juvenile Atlantic sturgeon have been found generally south of Kingston (RM90)



Source: Blossom, 1976

FIGURE 2-16

COMMERCIAL LANDINGS OF AMERICAN SHAD FOR THE HUDSON RIVER VALLEY. DOTTED LINES INDICATE GAPS IN RECORD.



Source: Blossom, 1976

FIGURE 2-17

COMMERCIAL LANDINGS OF ALEWIVES AND STRIPED BASS FOR THE HUDSON RIVER VALLEY. DOTTED LINES INDICATE GAPS IN RECORD.

TABLE 2-10

ENDANGERED, EXTIRPATED AND EXTINCT WILDLIFE OF NEW YORK STATE

RESIDENT ENDANGERED SPECIES

Indiana bat[1]	Myotis sodalis
Northern bald eagel[2]	Haliaeetus leucocephalus alascanus
American osprey[2]	Pandion halieatus carolinensis
Bog turtle[2]	Clemmys muhlenbergi
Shortnose sturgeon[1]	Acipenser brevirostrum
Blue pike[1]	Stizostedion vitreum glaucum
Longjaw cisco[1]	Coregonus alpenae
Karner blue butterfly[2]	Lycaeides melissa samuelis
Cjittenango ovate amber snail[2]	Succinea ovalis chittenangoensis

MIGRANT ENDANGERED SPECIES

Southern bald eagle [1]	Haliaeetus leucocephalus leucocephalus
Artic peregrine falcon[1]	Falco peregrinus tundrius

EXTIRPATED SPECIES

American peregrine falcon[1]	Falco peregrinus anatum
Eastern timber wolf[1]	Canis lupus lycaon
Eastern puma or cougar[1]	Felis concolor cougar - possibly extinct subspecies
Elk	Cervus canadensis canadensis
Moose	Alces alces americana
Eskimo curlew[1]	Numenius borealis - possibly extinct

EXTINCT SPECIES

Gull Island vole	Microtus nesophilus
Labrador duck	Camptorhynchus labrodorius
Heath hen	Tympanuchus cupido
Carolina parakeet	Conuropsis carolinensis
Passenger pigeon	Ectopistes migratorius

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[1] Indicates that the species is on the Federal and New York State Endangered Species lists.

[2] Indicates that the species is only on the New York State Endangered Species lists.

Source: NYCRR Section 182.1, Title 6.

during May to July. In the fall, juveniles move into deeper sections of the Hudson for over-wintering and adults leave the estuary for the winter months. At this time, some juveniles, 1-6 years of age, emigrate from the Hudson River moving south along the Atlantic coast to other estuaries. There is no recreational fishery for Atlantic sturgeon at present in the Hudson River. Commercial fishing efforts have been largely ineffective in the capture of this species.

2.82 The life history of the shortnose sturgeon is not as well known as that of the Atlantic sturgeon. Shortnose sturgeon are found throughout the Hudson River south of Albany-Troy (RM150), (Dovel, 1979). During the winter, shortnose sturgeon occur in the brackish portion of the Hudson, but primarily are found in freshwater areas upstream from Kingston (RM90). Mature fish appear to move upstream in early spring to spawning grounds located between RM115-135 (see Figure 2-2). There is evidence suggesting that some fish may ? also spawn in the fall. After spawning, spent sturgeon move downstream into more saline areas, possibly into the Atlantic Ocean for an unknown period of time before returning to the Hudson to spawn. Larval and juvenile shortnose sturgeon (less than 5 cm total length) have been found in the Hudson River between Germantown (RM107) and Coeymens (RM 132). Older young-of-the-year have also been found in the vicinity of New Baltimore (RM130). To be conservative, it should be assumed that the 97 mile area between Haverstraw Bay (RM36) and Coeymens (RM132) represents the nursery area for larval, junvenile, and young-of-the-year shortnose sturgeon. The population of adult shortnose sturgeon in the Hudson is estimated to be about 6000 fish. However, this estimate is uncertain because of the low number of marked recaptures, and the actual size of the population could range from 2000 to 21,000.

? Not definitively so.

2.83 Certain species of native plants are protected by law in New York (New York Environmental Conservation Law 9-1503), making their destruction illegal. These are listed in Table 2-11. Selected species of plants from the list of endangered and threatened species of plants prepared by the Smithsonian Institution (Smithsonian Institution, 1975) are identified in Table 2-12. On the basis of habitat, those plants that could be found in the Hudson River drainage basin are included in Table 2-12. The whorled pogonia orchid (Isotria medeoloides) is the only species that appears as endangered in both the Smithsonian Institution's list and the current list of the U.S. Department of the Interior. The latter list is constantly being expanded.

Ban on Commercial Fishing in the Hudson River

2.84 On 7 August 1975, following confirmation of the presence of polychlorinated biphenyls (PCB) in the Hudson River, the New York

TABLE 2-11

NATIVE PLANTS PROTECTED IN NEW YORK STATE

COMMON NAME	SCIENTIFIC NAME
Green-dragon (Dragonroot)	*Arisaema dracontium*
Butterfly-weed (Chigger-flower; Orange Milkweed; Pleurisy-root)	*Asclepias tuberosa*
Bluebell-of-Scotland (Harebell)	*Campanula rotundifolia*
American Bittersweet (Waxwork)	*Celastrus scandens*
Pipsissewa (Prince's-pine; Wax-flower) Spotted Evergreen (Spotted Wintergreen)	*Chimaphila spp.*
Flowering Dogwood	*Cornus florida*
Sundew (Daily-dew; Dewthread)	*Drosera spp.*
Trailing Arbutus (Ground Laurel; Mayflower)	*Epigaea repens*
Burning-bush (Wahoo) Strawberry-bush (Bursting-heart)	*Euonymus spp.* (Native)
All ferns, including: Adder's-tongue, Azolla, Buckhorn, Cliff Brake, Curly-grass, Fiddleheads, Hart's-tongue, Maidenhair, Moonwort, Polypody, Rock Brake, Salvinia, Spleenwort, Walking-leaf, Wall-rue, Water-spangle, Woodsia. **But excluding Bracken** *(Pteridium aquilinum)*; **Hay-scented Fern** *(Dennstaedtia punctilobula)*; **Sensitive Fern** *(Onoclea sensibilis)*, **which are not protected.**	*Filices (Filicinae; Ophioglossales* and *Filicales)* (Native)
Ague-weed, Blue-bottles, Gentian (Gall-of-the-earth)	*Gentiana spp.*
Golden Seal (Orange-root; Yellow Puccoon)	*Hydrastis canadensis*
Holly (Hulver); Inkberry (Bitter Gallberry); Winterberry (Black Alder)	*Ilex spp.* (Native)
Laurel, Spoonwood (Calico-bush) Wicky (Lambkill)	*Kalmia spp.*
Lily, Turk's-cap	*Lilium spp.* (Native)
Cardinal-flower (Red Lobelia)	*Lobelia cardinalis*
All Clubmosses, including: Bear's-bed (Christmas-green, Running Evergreen; (Trailing Evergreen; Ground Pine); Bunch Evergreen; Festoon Pine (Coral Evergreen; Buckhorn; Staghorn Evergreen; Wolf's-claws); Ground Cedar (Creeping Jenny); Ground Fir; Heath Cypress	*Lycopodium spp.*
Bluebell (Roanoke-bells; Tree Lungwort; Virginia Bluebell; Virginia Lungwort; Virginia Cowslip)	*Mertensia virginica*

TABLE 2-11 (Concluded)

COMMON NAME	SCIENTIFIC NAME
American Bee-balm; Oswego Tea (Indian-heads; Scarlet Bee-balm)	*Monarda didyma*
Bayberry (Candleberry)	*Myrica pensilvanica*
Lotus (Lotus Lily; Nelumbo; Pond-nuts; Water Chinquapin; Wonkapin; Yellow Lotus)	*Nelumbo lutea*
Prickly Pear (Wild Cactus; Indian Fig)	*Opuntia humifusa* *(O. compressa, p.p.)*
All Native Orchids, including: Adder's-mouth (Malaxis); Arethusa(Dragon's-mouth; Swamp-pink;)Bog-candle (Scent-bottle); Calopogon (Grass-pink; Swamp-pink); Calypso (Fairy-slipper); Coral-root; Cypripedium (Lady's-slipper; Moccasin-flower; nerve root); Goodyera (Lattice-leaf; Rattlesnake-plantain); Kirtle-pink; Ladies'-tresses (Pearl-twist; Screw-auger); Orange-plume; Orchis; Pogonia (Beard-flower; Snake-mouth); Putty-root (Adam-and-Eve); Soldier's-plume; Three-birds; Twayblade; Whipporwill-shoe	*Orchidaceae*
Golden-club	*Orontium aquaticum*
Ginseng (Sang)	*Panax quinquefolius*
Wild Crabapple	*Pyrus coronaria*
Azalea; Great Laurel (White Laurel); Honeysuckle; Pinxter (Election-pink; Pinxter-bloom); Rhododendron (Rosebay); Rhodora	*Rhododendron spp.* (Native)
Bitterbloom (Marsh-pink; Rose-pink; Sabatia; Sea-pink)	*Sabatia spp.*
Bloodroot (Puccoon-root; Red Puccoon)	*Sanguinaria*
Pitcher-plant (Huntsman's-cup; Sidesaddle-flower)	*Sarracenia purpurea*
Wild Pink	*Silene caroliniana*
Bethroot (Birthroot; Squawroot; Stinking Benjamin; Wake-robin); Toadshade, Trillium	*Trillium spp.*
Globe-flower (Trollius)	*Trollius laxus*
Bird's-foot Violet	*Viola pedata*

Source: NYCRR 193.3, 1974 Environmental Conservation Law 9-1503 (State of New York)

TABLE 2-12

ENDANGERED AND THREATENED PLANT SPECIES OF NEW YORK STATE ON THE LIST OF THE SMITHSONIAN INSTITUTION

COMMON NAME	SCIENTIFIC NAME	STATUS	HABITAT
Whorled Pogonia orchid	Isotria medeoloides	E	dry woodland
Reed-Bentgrass	Calamagrostis perplexa	E	rocky woods
Hart's Tongue	Phyllitis scolopendrium	E	cool well holes
Rattlesnake-Root	Prenanthes boottii	T	mountains
Rockrose	Helianthemum dumosum	T	dry sands, barrens, open woods
Ram's Head	Cypridedium arietinum	T	damp woods, bogs
Small White Lady's Slipper	Cypripedium candidum	T	calcareous meadows, prairie
Twayblade	Listera Auriculata	T	alluvial banks
Orchid	Platanthera leucophaea	T	woodlands
Orchid	Platanthera peramoena	T	woodlands
Reed-Bentgrass	Calamagrostis porteri	T	dry woodlands
Panic-Grass	Panicum aculeatum	T	swampy woods
Meadow Grass	Poa paludigena	T	bogs, swamps
Pondweed	Potamogeton hillii	T	wetlands, ponds
Curly-Grass	Schizaea pusilla	T	low wet areas, shores
Agalinis	Agalinis acuta	T	sandy banks
Micranthemum	Micranthemum micranthemoides	T	tideflats

Sources: Smithsonian Institution, 1975; Fernald, 1970.

State Department of Environmental Conservation issued a press release advising against the consumption of fish taken from the Hudson River. On 26 February 1976, the Department imposed a ban on commercial fishing in certain portions of the Hudson River and its tributaries and the sale of fish taken in these waters.

2.85 New York State regulations (6 NYCRR 12.19) now prohibit commercial fishing in the Hudson River upstream from the Troy Dam to Fort Edward and downstream of the dam to the Battery and in all tributary waters along these reaches upstream from the river to the first falls or barriers impassable to fish. The ban applies to all fish, including American eel, except Atlantic sturgeon greater than 4 feet in length, goldfish and American shad. Regulations have been modified slightly to allow the taking of bait fish.

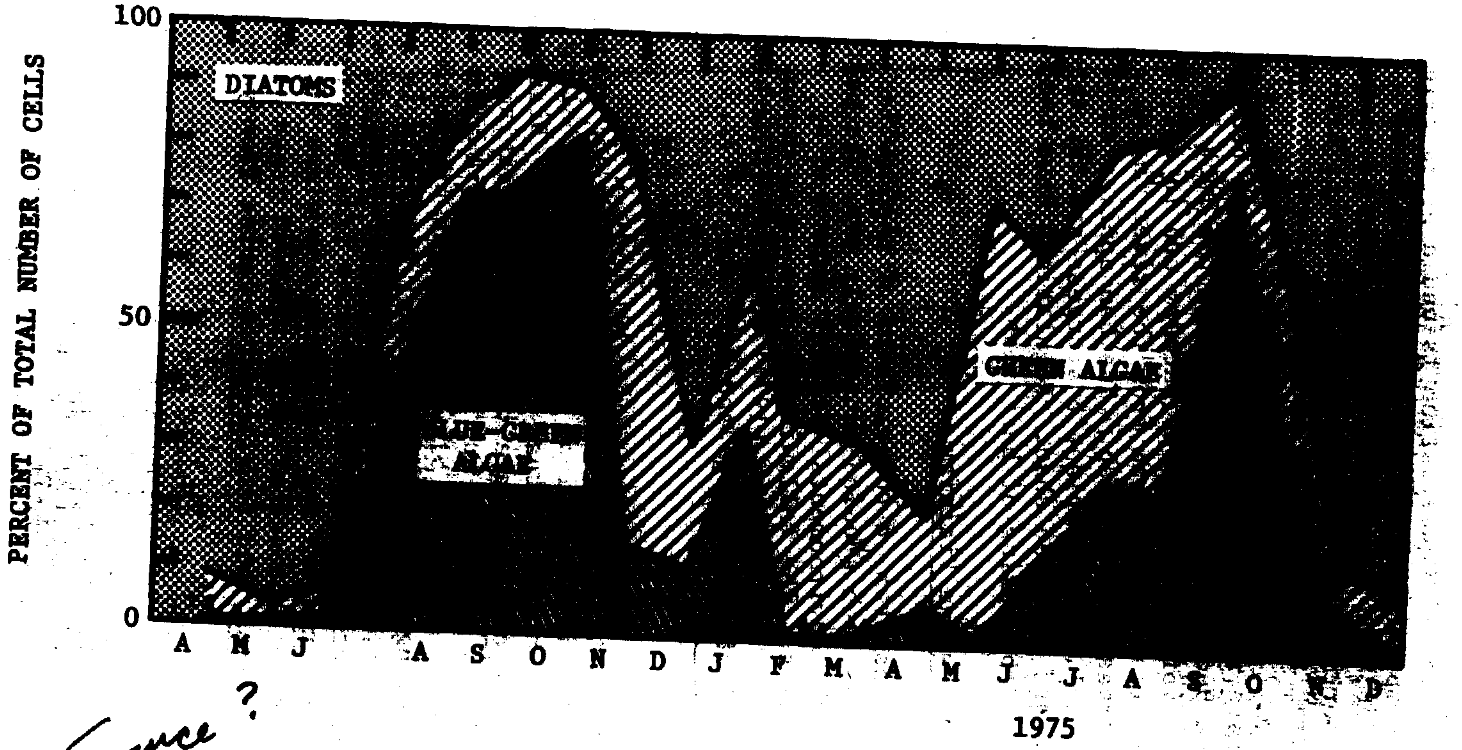
Aquatic Ecosystems of the Bowline Vicinity

2.86 The aquatic ecosystem in the vicinity of the Bowline Point Generating Station has been studied extensively over the past several years as part of the environmental studies sponsored by Orange and Rockland Utilities. The following discussion is drawn primarily from Quirk, Lawler, and Matusky (1974) and Lawler, Matusky, and Skelly (1975a, 1976a, 1978) and Orange and Rockland (1977).

Phytoplankton

2.87 The seasonal pattern of phytoplankton species succession observed in the Bowline vicinity is typical of that occurring along much of the rest of the Hudson River estuary (Figure 2-18). Diatoms, predominantly *Melosira* and *Cyclotella*, are the dominant organisms during the winter and spring. *Navicula* and *Asterionella* are also important from year to year. Green and blue-green algae predominate in the summer and fall. Among the blue-green algae, *Anacystis* is a dominant occurring every year, while *Ocillatoria*, *Gomphosphaeria*, and *Gleotrichia* are other dominants varying in occurrence from year to year. *Stichococcus* and *Ulothrix* are the dominant green algae with consistent occurrence. The occurrence of other dominant green algae such as *Pediastrum*, *Scenedesmus*, and *Ecballocystis* varies from year to year.

2.88 Seasonal abundance of phytoplankton is characterized by a spring bloom in May or June. Usually the dominant bloom organisms are diatoms, but in 1975 it was the green algae *Stichococcus*. A secondary abundance peak also often occurs in the fall. Seasonal patterns of phytoplankton in Bowline Pond are usually similar to that in the Hudson River.



Source?

FIGURE 2-18

SEASONAL PATTERN OF DOMINANCE IN PHYTOPLANKTON IN THE HUDSON RIVER IN THE VICINITY OF THE BOWLINE POINT GENERATING STATION

Microzooplankton

2.89 The dominant microzooplankton in the Bowline Point vicinity are copepods, cladocerans, and rotifers. Occasionally, other species are seasonally important. Copepods are usually the most abundant species at all times of the year.

2.90 Seasonal patterns of species succession are linked to the salinity regime in the Bowline Point area, to temperature changes, and possibly to fluctuations in other environmental conditions such as nutrient levels. In the spring and early summer when river flow is still large and the waters at Bowline Point are not saline, the microplankton are dominated by cyclopoid copepods, cladocerans, and rotifers. By late summer and fall, river flow declines and the salinity rises to several parts per thousand. During this period, cladocerans and rotifers decline to low numbers and calanoids become the dominant copepod. Freshwater species return in winter as river flow increases. Spring and fall peaks in abundance have been noted at Bowline Point. The two peaks are usually copepods or rotifers.

Macrozooplankton

2.91 Amphipods, dipterans, cladocerans, and isopods are the predominant macrozooplankton in the Bowline area. Amphipods, dipterans, and isopods are also found as part of the benthic community. Cladocerans are completely planktonic.

2.92 Trends in abundance of macroplankton are similar to those of microplankton. Spring and fall peaks of amphipods (mostly *Gammarus* and *Monoculoides*) occur when freshwater flow is large. Cladocerans (*Daphnia* and *Leptodora*), another freshwater species, are also abundant in the spring. Dipterans and isopods are less abundant relative to other kinds of macrozooplankton at all times, and are less correlated with salinity changes.

Benthos

2.93 Benthic communities are similar throughout the Bowline area because of the relative homogeneity of the sediments. Molluscs, polychaete and oligochaete worms, dipterans, and crustaceans (primarily harpacticoid copepods, isopods, and amphipods) are the dominant organisms in both numbers and biomass. Organism abundance is greatest in the spring and winter, with lesser numbers in the summer. Biomass is greatest in the spring and summer and less in the fall and winter. Molluscs are represented almost exclusively by the gastropod snail *Amnicola*. Oligochaete worms were primarily *Peloscolex benedeni* and *Limnodrilus hoffmeisteri*. *Scolecolepides* and *Hypaniola* were common polychaete worms. Amphipod crustaceans are represented by Corophium, Monoculoides, and three species of Gammarus. Common isopod crustaceans are Cyathura, Chiridotea, and Edotea. Procladius is the common dipteran arthropod. Occurrence and relative dominance of any particular species is variable from year to year. Some seasonal variation in species composition occurs, primarily due to increases in abundance of harpacticoid copepods, isopods, and amphipods during the warmer months.

Fish Eggs and Larvae

2.94 The concentration of fish eggs in the vicinity of Bowline Point is generally low, supporting other studies indicating that major spawning areas of anadromous fishes are further upstream and downstream. Eggs of the following species have been collected in the Hudson River near Bowline Point: Atlantic tomcod, white perch, striped bass, Alosa spp., Morone spp., and the bay anchovy (Lawler, Matusky, and Skelly Engineers, 1978). During the period of February to July, fish eggs collected at Bowline Point were primarily those of the bay anchovy, which spawns in June and July (see Table 2-13). Morone spp. (white perch and striped bass) spawn earlier in the season during May and June and may contribute substantial numbers of eggs at these times. Egg concentrations in Bowline Pond are usually considerably less than in the river, sometimes 10 percent or less. The species composition of fish eggs in Bowline Pond is similar to that observed in the river proper (Quirk, Lawler and Matusky, 1974).

these are S.B.+W.P.

2.95 Seasonal abundance and species composition of larvae vary with the spawning patterns of the dominant species in the estuary. Three peaks of larval abundance generally occur (see Figure 2-19). The larvae of Atlantic tomcod (a winter spawner) appear in greatest numbers in late winter and early spring. Another peak of larval concentration occurs in May through early July composed primarily of striped bass, white perch, and species of Alosa (alewife, blueback herring, and shad). Bay anchovy larvae become numerous during mid-June to mid-September. Other species contribute a relatively small percentage of larvae to the total throughout the warmer months. Mean monthly fish larvae abundance in Bowline Pond generally ranges between 60 percent and 10 percent of abundance at Bowline Channel (Lawler, Matusky and Shelly Engineers, 1976).

Fish

2.96 The fish community of the Bowline Point vicinity is typical of the oligohaline areas of the Hudson River Estuary. Atlantic tomcod, white perch, hogchoker, bay anchovy, striped bass, alewife, and blueback herring are the dominant members of the community. Actual abundance and relative dominance of each species is

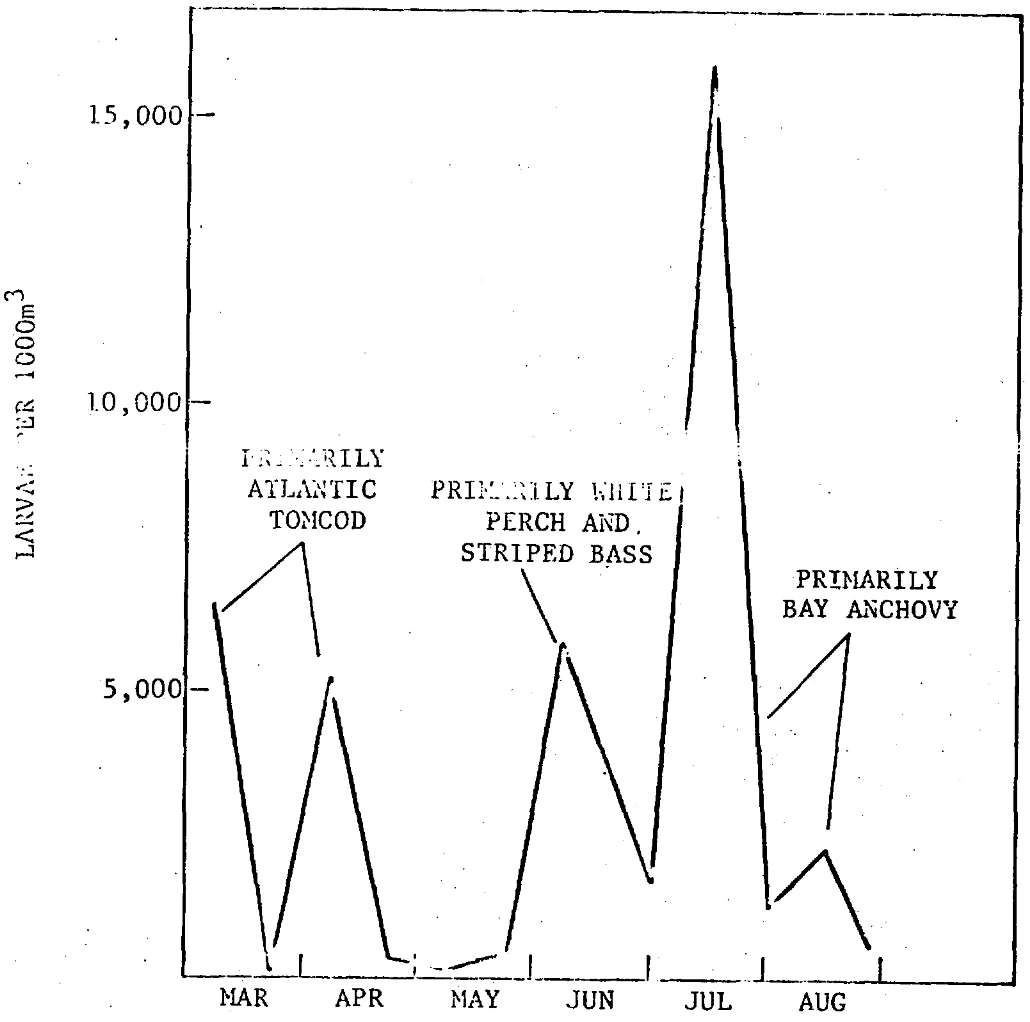
TABLE 2-13

FISH EGG ABUNDANCES IN THE HUDSON RIVER AT BOWLINE POINT DURING 1977

DATE	FISH EGG ABUNDANCE (no./1000m^3)	
	TOTAL[a]	BAY ANCHOVY
24 February	0	0
08 March	0	0
15 March	0.3	0
29 March	0	0
31 May	18	18
02 June	2.7	2.3
06 June	14.0	1.3
08 June	4.3	4.3
13 June	784.3	784.3
16 June	3767.0	3765.0
20 June	56.3	26.3
23 June	24.3	24.3
27 June	536.3	536.3
30 June	4.0	4.0
05 July	0	0
12 July	7159.3	7159.3
19 July	301.6	301.6
26 July	1121.6	1121.6

[a] Averaged from 3 sampling transects, at all depths and sampling times.

Source: Lawler, Matusky, and Skelley, 1978; Table IV-4.



Source: Lawler, Matusky, and Skelly (1978), Table UB-23

FIGURE 2-19
SEASONAL VARIATION IN DENSITIES OF FISH LARVAE
AT BOWLINE POINT

variable from year to year depending on such factors as year class strength, seasonal river flow, and salinity in the Bowline area. Overall seasonal abundance is greatest in the river from mid-summer through mid-fall. Seasonal abundance of fish species in the Bowline area is consistent with the life cycle of each species.

2.97 The species composition in Bowline Pond is different from that in the river. Blueback herring, redbreast sunfish, banded killifish, and white perch are the dominant species.

Aquatic Ecosystems of the Roseton Vicinity

2.98 The aquatic ecosystem in the vicinity of the Roseton Power Generating Station has been studied extensively as part of environmental studies sponsored by Central Hudson Gas and Electric. The following discussion is drawn from Quirk, Lawler, and Matusky (1973) and Lawler, Matusky, and Skelly (1975b, 1976b), and Central Hudson Gas and Electric (1977).

Phytoplankton

2.99 The seasonal pattern among the phytoplankton observed at the Bowline point generating station of diatom dominance in the winter and spring shifting to green and blue-green algae in the summer and fall is also the typical pattern in the vicinity of Roseton. Common diatoms include *Coscino-discus*, *Cyclotella*, *Melosira*, *Asterionella*, *Navicula*, and *Nitzschia*. *Cyclotella* and *Melosira* are the most frequent dominants with the others varying in importance from year to year. The dominant green algae are *Eudorina*, *Pediastrum*, *Scenedesmus*, *Tetrastrum*, *Ulothrix*, *Panadorina*, and *Mougeotia*. Frequently occurring blue-green algae include *Oscillatoria*, *Chroococcus*, *Aphanocapsa*, *Microcystis*, *Lyngbya*, *Merismopedia*, and *Anacystis*. The particular dominants are variable from year to year among the green and blue-green algae.

Microzooplankton

2.100 Copepods, cladocerans, and rotifers are the dominant microzooplankters in the Roseton vicinity. Abundance is similar to that at Bowline Point but seasonal shifts in species at Bowline Point related to salinity are not observed at Roseton because of the predominantly freshwater regime. Copepod nauplii and rotifers are often the most numerous organisms during all but the dryest years. *Bosmina* is the dominant cladoceran. Important rotifers are *Keratella*, *Brachionus*, and *Nothulca*. No distinctly repeating seasonal pattern of species composition is usually evident.

?

Macrozooplankton

2.101 Amphipods (*Gammarus* sp.), dipteran larvae, and *Leptodora* (a cladoceran) are the most abundant macrozooplankters in the vicinity of the Roseton Generating Station. One or two peaks of abundance occur, usually in the early summer and/or fall. The microplankton exhibit daily vertical migration, being more evenly distributed throughout the water column during the night and concentrated at greater depths during the day.

Benthos

2.102 Tubificid oligochaete worms and dipteran larvae dominate the benthic community in the Roseton vicinity. Isopods, amphipods, decapods, turbellarians, polychaetes, leeches, arachnids, molluscs, and other insect groups are less common. *Limnodrilus hoffmeisteri* is the dominant oligochaete. *L. udekemianus*, *L. profundicola*, *Stylaria Fossularia*, *Vejdovskyella intermedia*, *V. Comata*, and *Aulodrilus pluriseta* are found less frequently. The most frequently occurring dipteran larvae are the chironomids *Coelotanypus* sp. and *Polypedilum* sp. Other groups, such as biting midges (Ceratopognidae) and the phantom midge (*Chaeoborus* sp.) are sometimes seasonally abundant.

2.103 Community structure and organism abundance generally has been similar at all sites sampled in the estuary near Roseton, probably because of the relatively homogeneous sediment characteristics of the area. Occasionally, abundance at one or two stations would be statistically different from other stations. No clear overall trends in seasonal abundance of total macrofauna and seasonal species composition are evident.

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Fish Eggs and Larvae

2.104 Two major periods of fish larvae abundance occur in the Roseton vicinity (Figure 2-20). The first is in late winter and consists of Atlantic tomcod. During the second period, striped bass, white perch, and *Alosa* sp. larvae appear in greatest numbers in late May, June and early July, usually peaking in June. Other species most numerous in June were tessellated darter (*Etheostoma olmstedi*) and cyprinids (*Carassius auratus*, *Cyprinus carpio*, *Notropis* spp.). Other species identified were rainbow smelt (*Osmerus modax*), sunfish (*Lepomis* spp.), yellow perch (*Perca flavescens*), killifish (*Fundulus* spp.) and sturgeon (*Acipenser* spp.). The bay anchovy (*Anchoa mitchilli*) is present in low numbers in July and August.

2.105 Limited data on fish egg abundance and occurrence is available for Roseton. Sampling during 1974 showed low numbers of eggs in May and June, peaking in early May at an average

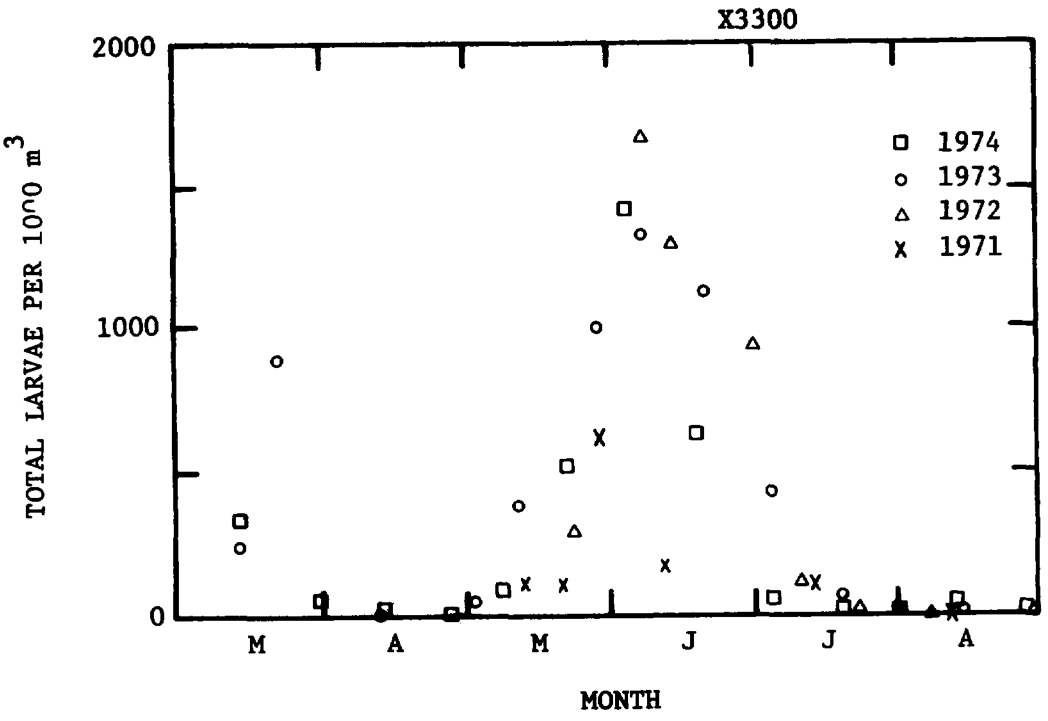

FIGURE 2-20

OCCURRENCE OF FISH LARVAE IN THE HUDSON RIVER
AT THE ROSETON POWER GENERATING STATION

concentration of 45.7 eggs per 1000 cubic meters of water. Other samples contained less than five eggs per 1000 cubic meters.

Fish

2.106 In any single year, 8 or 10 species usually make up the majority of the fish community in the vicinity of Roseton as measured by trawling, gillnetting, seining, and trapping. White perch and blueback herring usually account for 35 percent or more of the catch. Other species are more variable in their relative abundance from year to year. Atlantic tomcod is the most variable, representing 34.5 percent of the catch in 1972, but only 3 and 7.7 percent in 1973 and 1974, respectively. Alewife, American shad, spottail shiner, golden shiner, other *Alosa* species, brown bullhead, pumpkin-seed sunfish, striped bass, bay anchovy, hogchoker, white catfish, and American eel have all represented more than 1 percent of the catch in at least one sample year. Striped bass are usually caught in relatively low numbers, representing 1.9 percent (1972), 4.6 percent (1973), and 0.9 percent (1974) of the catch over the sample period.

2.107 Total fish abundance is greatest during spring and summer. Species and age makeup of the fish community change throughout the year as adults migrate up and down the estuary and as young of the year grow and move in and out of the area.

HUMAN RESOURCES

2.108 The Hudson River estuary, as defined in the present study, supports a population (1975) of 11,400,000 (U.S. Department of Commerce, 1976a). The area* encompasses all or portions of three Standard Metropolitan Statistical Areas; namely, New York, Poughkeepsie, and Albany-Schenectady-Troy.

Population

2.109 Population statistics pertaining to the Hudson River estuary are given in Table 2-14. As the data indicate, the counties in the southernmost portion of the study area (Bergen and Hudson Counties in New Jersey and the City of New York) together with Westchester County account for a population of almost 10 million or 87 percent of the population within the entire study area. Albany and Rensselaer Counties, with a combined population of nearly 500,000, account for a further 4 percent. The balance of 9 percent of the population is distributed among the remaining seven counties which, in terms of geographical extent, make up approximately two-thirds of the study area. Population is not evenly distributed over these counties. There are notable concentrations in Rockland, Orange, and Dutchess Counties and low populations in Putnam, Columbia and Greene Counties. Population densities vary greatly over the study area, ranging from the extremely high densities of New York City (more than 25,000 persons per square mile) and Hudson County, New Jersey (12,400 persons per square mile), to a low of 59 persons per square mile in Greene County. Rockland County has a population density of 1,415 persons per square mile.

2.110 Population has been increasing in portions of the study area and decreasing in others. The number of residents increased substantially between 1970 and 1975 in Putnam (22.4 percent) and Greene (15.3 percent) Counties. Ulster (9.7 percent), Orange, Rockland and Columbia (7.0 percent) Counties experienced moderate growth over the same period. Growth was somewhat lower in Dutchess County (5.6 percent) and the population in Albany and Rensselaer Counties remained virtually stable (0.7 percent growth in both counties). Population decreased over the 1970-1975 period in New York City, Bergen and Hudson Counties in New Jersey and Westchester County. New York City and Hudson County both registered losses in excess of 4 percent. The population of New York City, the New Jersey Counties of

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*Counties adjacent to the Hudson River from the Albany-Troy area south to the Battery in Manhattan. For present purposes, the City of New York (Bronx, Kings, New York, Queens, and Richmond Counties) are treated as a single entity within the study area.

TABLE 2-14

POPULATION STATISTICS FOR THE REGION OF THE HUDSON RIVER ESTUARY

COUNTY	SQUARE MILES	1975 POPULATION	POPULATION DENSITY (Persons per Square mile)	POPULATION CHANGE (Percent) 1960-1970	POPULATION CHANGE (Percent) 1970-1975
Albany	526	288,900	549	-2.7	0.7
Rensselaer	665	153,600	231	-0.6	0.7
Greene	653	38,200	59	3.7	15.3
Columbia	645	55,100	85	4.6	7.0
Ulster	1,141	155,000	136	10.8	9.7
Dutchess	813	234,800	299	14.8	5.6
Orange	833	242,500	291	11.1	9.4
Putnam	231	69,400	300	65.6	22.4
Rockland	176	249,100	1,415	52.4	8.4
Westchester	443	877,000	1,980	2.5	-1.9
Bergen, N.J.	234	871,900	3,726	6.5	-2.8
Hudson, N.J.	47	582,800	12,400	-7.7	-4.1
New York City (1)	300	7,567,800	25,226	16.4	-4.2

Sources: U.S. Department of Commerce, 1976a.

(1) Bronx, Kings, New York, Queens and Richmond Counties.

Bergen and Hudson, and Westchester County decreased during the 1970 to 1975 period; New York City and Hudson Counties both registered losses in excess of 4 percent. Population in New York State as a whole declined by 0.7 percent over the same period, compared to a loss of 0.3 percent sustained in the decade between 1960 and 1970 (Rand McNally, 1976).

2.111 The population in Rockland County increased from 136,803 in 1960 to 229,903 in 1970, an overall increase of 68 percent (U.S. Department of Commerce, 1973). Growth moderated to an overall increase of 8.4 percent between 1970 and 1975, to reach 249,100 for 1975.* Population in the Town of Haverstraw, one of five townships forming Rockland County, increased from 16,632 in 1960 to 23,311 in 1970, an overall increase of 40 percent (U.S. Department of Commerce, 1976a). The population reached an estimated** 30,260 in 1975, representing a further increase of 30 percent.

Socioeconomic Profile

2.112 The Hudson River estuary is area one of the nation's principal centers of industrial, commercial and financial activities. Employment in the area (1970), as indicated by the selected socioeconomic statistics presented in Table 2-15, is oriented heavily towards the manufacturing industries. Trade (wholesale and retail) and government services represent the region's other major employment sectors. The volume of trade (retail sales) in the area is related to the distribution of population and is greatest in the southern and northern portions of the area, least in Columbia, Greene and Putnam Counties. Median family incomes in 1969 were lowest in Columbia and Greene Counties; the median income in Putnam County was considerably higher, due to its large suburban population.

2.113 The portion of land area devoted to farming declined in each of the counties in the study area between 1969 and 1974. The relative decrease was largest in the southern portion of the estuary, where the acreage in farming represented a relatively minor use of the land. Despite the decline, farms still (1974) occupy substantial portions of Columbia (37 percent), Orange (28 percent), Dutchess (27 percent), Rensselaer (26 percent) and Albany (23 percent) Counties, the noted dairying and fruitgrowing region of the Hudson River. Much of Greene and Ulster Counties lies in the Catskill Mountains, and relatively small portions of these counties are suitable for farming.

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*The Planning Board of Rockland County estimates the population figure to be 260,000; established by communication with the Board on 16 February 1977.

**Estimated by the Planning Board of Rockland County; established by communication with the Board on 16 February 1977.

TABLE 2-15

SOCIOECONOMIC CHARACTERISTICS (1)

COUNTY	BASIC TRAINING AREA (2)	TWO LARGEST EMPLOYMENT SECTORS, PERCENT EMPLOYED	SALES VOLUME (2) ($1,000's)	MEDIAN FAMILY INCOME	LAND IN FARMS (3)	
					PERCENT OF LAND, 1974	PERCENT CHANGE 1969-1974
Albany	Albany/Schenectady/Troy	Gov't, 29/Trade, 20	1,010,539	$11,015	23	-11
Rensellaer	Albany/Schenectady/Troy	Manuf, 23/Gov't, 21	223,637	10,084	26	-10
Greene	Albany/Schenectady/Troy	Manuf, 22/Gov't, 22	17,673	8,552	16	-14
Columbia	Albany/Schenectady/Troy	Manuf, 26/Trade, 17	27,403	8,709	37	-12
Ulster	Poughkeepsie/Kingston	Manuf, 29/Trade, 19	128,553	9,808	11	-11
Dutchess	Poughkeepsie/Kingston	Manuf, 33/Gov't, 19	232,506	11,658	27	-14
Orange	Newburgh/Middletown	Manuf, 23/Gov't, 20	235,261	10,128	28	-4
Putnam	New York City	Manuf, 20/Gov't, 17	15,468	11,995	5	-51
Rockland	New York City	Manuf, 22/Gov't, 21	293,537	13,751	1	-63
Westchester	New York City	Manuf, 21/Trade, 20	3,080,290	13,774	5	-15
Bergen, N.J.	New York City	Manuf, 30/Trade, 22	3,983,359	13,591	2	-50
Hudson, N.J.	New York City	Manuf, 35/Trade, 17	1,540,304	9,695	-	-
New York City (4)	New York City	Manuf, 19/Trade, 19	59,196,380	18,609	-	-

Sources: (1) U.S. Department of Commerce, 1973.
(2) Rand McNally, 1976.
(3) U.S. Department of Commerce, 1976b.
(4) Bronx, Kings, New York, Queens and Richmond Counties.

2.114 The median family income among residents of Rockland County in 1969 was $13,751, second only to the median income of Westchester County ($13,774) within the study area and considerably higher than the median income of $10,609 in New York State as a whole (U.S. Department of Commerce, 1973b). In 1970, there were 60,359 occupied housing units in the county, 70.4 percent of which were occupied by the owner (U.S. Department of Commerce, 1973b). The civilian labor force numbered 86,555 with 83,436 being employed. The breakdown (percent of labor force) of employment by employing sector in 1970 was:

Manufacturing	21.8
Wholesale and Retail Trade	19.2
Services	6.8
Educational Services	10.5
Construction	6.3
Government	20.8
Craftsmen and Foremen	12.6

The Bureau of the Census classified 59.7 percent of the labor force as white collar workers, made up of 32.4 percent professionals and 27.3 percent sales personnel.

Land Use

2.115 Selected statistics on land use for the counties forming the study area (except the City of New York) are given in Table 2-16. The information is derived from a survey conducted in 1958 and updated in 1967 by the Soil Conservation Service, (U.S. Department of Agriculture, 1967; 1970). Although the information may be outdated, it is the latest available set of data that applies consistently and is presented here to provide an overview of the urbanization pattern on the Hudson River estuary.

2.116 The data in Table 2-16 indicate that the New York counties of Putnam, Rockland and Westchester are almost completely urbanized. Bergen and Hudson Counties in New Jersey are heavily urbanized, although a sizable portion of Bergen County is forested. The remaining counties of the study area are less urbanized, and one-half or more of the area in each county is primarily forested. Greene and Ulster Counties, in particular, are heavily wooded and unurbanized. Catskill Park, a state reserve, occupies major portions of these counties. The major Federal land holding in the study area is the West Point U.S. Military Academy in Orange County.

2.117 A land use plan has been developed for Rockland County (County of Rockland, 1973). The northwestern portion of the county is occupied largely by the Harriman State Park. Residential

TABLE 2-16

LAND USE STATISTICS, EXCLUDING CITY OF NEW YORK

COUNTY	LAND AREA, ACRES	URBAN AND BUILTUP		FEDERAL NON-CROPLAND ACRES	INVENTORY ACREAGE(1)	PERCENT OF INVENTORY ACREAGE(2) IN		
		ACRES	PERCENT			CROPLAND	PASTURE	FOREST
Albany	339,840	36,373	11	597	302,000	26	7	55
Rensselaer	425,600	42,577	10	2	381,500	22	6	53
Greene	417,920	19,401	5	239	397,500	11	7	73
Columbia	411,520	10,935	3	7	399,390	33	13	47
Ulster	731,520	50,600	7	644	675,900	11	1	86
Dutchess	522,240	72,330	14	599	448,000	26	10	53
Orange	530,560	74,563	14	18,397	435,400	20	11	52
Putnam	150,400	149,800	99+	0	0	-	-	-
Rockland	113,920	113,450	99+	70	0	-	-	-
Westchester	278,400	277,485	99+	15	0	-	-	-
Bergen, N.J.	149,100	119,900	80	100	28,500	14	0	81
Hudson, N.J.	28,800	26,200	91	900	1,600	-	-	-

(1) New York Conservation Needs Inventory and New Jersey Conservation Needs Inventory of 1967; see sources listed below.

(2) Includes only private, rural land.

Sources: U.S. Department of Agriculture, 1967; 1970.

developments predominate in the remainder of the county, with zones designated for industrial and commercial development present in each of the five townships forming the county. The Palisades Interstate Parkway traverses the county from north to south, and the New York State Thruway from east to west in the southern portion of the county.

Historical Resources

2.118 The Hudson River Estuary is rich in sites and landmarks of historic interest, legacies of the eventful development of one of the longest settled areas in North America. In addition, eminent examples of the architectural style of each of the eras in the region's history abound. The National Register of Historic Places (U.S. Department of the Interior, 1977) contains an extensive list of properties within the Hudson River estuary. Table 2-17 lists properties within 5 miles of the Bowline Point and Roseton Generating Stations. Two properties in the immediate vicinity of the Bowline Point Generating Station are included in the Register. These are the Henry Garner Mansion located approximately one mile from the power plant site, and the Fraser-Hoyer House, also in West Haverstraw. Directly across Haverstraw Bay is the Van Cortlandt Manor, a National Historic Landmark. The Stony Point Battlefield is another National Historic Landmark, located approximately 3 miles north of the power plant site.

2.119 In addition, New York State currently has an active historic preservation program within the Parks and Recreation Department. The Department has on file several structures and sites that are potentially eligible for inclusion in the National Register. Table 2-17 lists properties in the vicinity of the Bowline Point and Roseton Generating Stations that have been nominated or approved by New York State* but have not to date (1 March 1977) been included in the National Register (36 CFR 800) as of 1 March 1977 and become subject to the provisions of the National Historic Preservation Act.

update this:-

2.120 An inventory of historic resources of the Hudson River Valley (Hudson River Valley Commission, 1969) lists several structures of architectural interest in the Town of Haverstraw and the Villages of Haverstraw and West Haverstraw. These are predominantly houses built in the early and middle 19th Century, several churches from the same period and one instance of a two-story clapboard house dating from around 1770.

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*Information on places nominated but not in the National Register has been obtained through personal communication by Mr. Joel Klein, Historic Preservation Program Analyst, New York State Parks and Recreation Department, 4 March 1977.

TABLE 2-17

HISTORIC SITES IN THE VICINITY OF THE BOWLINE POINT AND ROSETON GENERATING STATIONS

Rockland County

Stony Point, Stony Point Battlefield, north of Stacy Point on US 2 and 202
West Haverstraw, Fraser-Hoyer House, Treason Hill, off US 9W
West Haverstraw, Henry Garner Mansion, 18 Railroad Avenue
Palisades Interstate Park, west bank of the Hudson River
New City, New Hempstead Presbyterian Church and School House*

Westchester County

Croton-on-Hudson, Van Cortlandt Manor US 9N of junction with US 9A

Ulster County

None

Orange County

Newburgh, David Crawford House, 189 Montgomery St.
Newburgh, Dutch Reformed Church, NE corner of Grand and 3rd Sts.
Newburgh, Mill House (Gomez the Jew House) Mill House Rd.
Newburgh, Montgomery-Grand-Liberty Streets Historic District, 19th-20th St.
Newburgh, Washington's Headquarters (Hasbrouck House), Liberty and Washington Sts.

Dutchess County

Beacon, Madame Catharyna Brett Homestead, 50 Van Nydeck Ave.
Beacon, Howland Library, 477 Main St.
Beacon, Tioronda Bridge, South Ave.
Fishkill, Fishkill Village District, along N.Y. 52 from Cary St. to Hopewell St.
Fishkill vicinity, Fishkill Supply Depot Site
Fishkill vicinity, Van Wyck-Wharton House, south of Fishkill on US 9
Verplanck, Verplanck-Van Wyck Barn, town of Wappinger*
Beacon, Eustatis, NW of Beacon of N.Y. 9D*

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*Denotes sites nominated to or approved by New York State for nomination to, but not on, the National Register of Historic Places as of 1 March 1977.

Recreational Resources

2.121 A broad range of recreational resources exists along the Hudson River and within the contiguous counties. The river provides opportunities for noncontact recreation such as boating, fishing, bird-watching and, in addition, swimming in some areas. The river provides a backdrop for camping, hunting, hiking, sightseeing and motoring.

2.122 The study area contains numerous skiing resorts, state parks, such as Catskill Park and the Palisades Interstate Park, and many other smaller recreational facilities. There are many private and semiprivate resorts, country clubs and other recreational facilities in the area.

CHAPTER 3

RELATIONSHIP OF THE PROJECT TO LAND USE PLANNING

3.01 The Bowline Point Generating Station occupies a 245-acre tract in the Town of Haverstraw and Village of West Haverstraw, Rockland County, New York.* Located approximately 30 miles north of New York City, the Town of Haverstraw is one of several established centers of industry and commerce along the Hudson River between the Albany-Troy, Schenectady and New York metropolitan areas.

3.02 Haverstraw was incorporated as a village in 1854 with a mayor-council system of government. The original village gained rapidly in importance following the introduction of steam navigation on the Hudson River in 1807. Traprock quarrying became one of the major activities in the area. Other industries, which at one time thrived or are still active, include the manufacture of cement, brick and other building products, paint, hardware, textiles, and leather and metal novelties.

3.03 The riverfront areas of the Town of Haverstraw and the adjacent Town of Stony Point to the north have been traditional sites of clay quarrying and brick manufacturing. Deposits of coal ash and debris from these activities and other industrial rubble remain in the area. The power plant site, originally part of the Grassy Point Marsh formed by the deltas of the Cedar Pond Brook and Minisceongo Creek, most recently had been used as a municipal landfill and for the unauthorized disposal of discarded automobiles, household applicances and trash (Orange and Rockland, 1971).

3.04 Preparation owrk at the site included the removal of garbage, vegetative clearing, pest control, filling, grading and drainage improvements. Approximately 60 acres of wetlands were affected by the construction of the power plant and associated facilities. All major site work and construction related to the Bowline Point Station and the recreational facility on site is now complete. The power plant is a prominent visual feature in the view from the river and is visible from many residential sections and a considerable length of shoreline.

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*Counties in New York are subdivided into legally incorporated towns, also referred to as townships, and cities. With one exception (the City of Sherrill in the Town of Vernon, Oneida County), towns and cities are independent civil entities. In addition, there are incorporated villages, each lying within one or more towns. New York comprises 930 towns, 62 cities and 533 villages (Rand McNally, 1976).

RELATIONSHIP TO LOCAL LAND USE

3.05 Rockland County in its land use plan designates the site of the Bowline Point Generating Station as a utility zone and the area immediately to the northwest of the site as an industrial zone (County of Rockland, 1973). Adjacent to these are zones of high density (five or more dwelling units per acre) and medium density (two to four dwelling units per acre) residential development and zones of commercial development. Modest homes forming well-established neighborhoods, small retail businesses and public buildings predominate in the vicinity of the power plant.

3.06 There is no indication that the Bowline Point Generating Station has had any tangible effect on land use in the villages of Haverstraw and West Haverstraw or in the greater area of the Town of Haverstraw. Property values generally have not declined since 1973, despite completion and operation of the power plant and the stagnant economic conditions in southeastern New York over the period (Rotella, 1977). The area has experienced no abnormal growth or decline in population nor discernible changes in urbanization patterns, industrialization or business activities (Rotella, 1977).

3.07 Development of the site has entailed the loss of some open space of marginal recreational value. On the other hand, the owners of the plant have contributed substantially otwards the establishment of the Bowline Point Municipal Park and related amenities. The facility proved to be a popular local attraction during its first year of operation and it is anticipated that public use of the facility will increase in coming years (Rotella, 1976, 1977).

3.08 The station provides employment for a permanent work force of approximately 100 (U.S. Federal Power Commission, Form No. 1, Annual Report of Orange and Rockland Utilities, Inc., 31 December 1976) that includes trained plant operators, administrative personnel and maintenance staff. Employees commute to the site from a wide area. The plant operates 24 hours a day in three shifts and, during shift changes, automobile traffic to and from the plant increases but causes no appreciable congestion on local roads (Rotella, 1976, 1977).

up to

3.09 Subsequent to the improvements in access to the site made during the construction phase of the project, no need to upgrade local highways or railroads has become evident. Fuel oil is delivered to the site by barge or tanker. The added river traffic is readily accommodated and poses no undue hazard to waterborne commerce or pleasure boating. Occasional deliveries of equipment and materials to the power plant constitute a minor added demand on railroad and highway transportation systems serving the area.

3.10 The land use plan of the County of Rockland shows that part of the waterfront in the Town of Haverstraw remains dedicated to industrial development (County of Rockland, 1973). Improvements at the Bowline Point site have generally upgraded the industrial potential of the area through enhanced drainage and access to the site and the termination of trash disposal. These improvements, together with a strengthening of the municipal tax base, might constitute an attraction to future industrial ventures in the area.

3.11 The station's visibility and visual dominance evidently have not affected local and use to a discernible degree. The extent to which these factors might influence future development or redevelopment in the area is difficult to gauge, particularly if massive natural draft cooling towers are installed. The presence of the power plant is certain to contribute heavily to the industrial, character of its surroundings and may inhibit certain types of residential, commercial or recreational developments.

3.12 Operation of the Bowline Point Generating Station is unlikely to influence future land use planning or development as a result of the plant's consumption of water, discharge of airborne emissions and liquid effluents, generation of solid wastes, and interaction with the aquatic ecosystem of the Hudson River.

RELATIONSHIP TO LAND USE ON THE HUDSON RIVER ESTUARY

3.13 For several years electrical generating facilities have provided a focus for concerns over the effects of urbanization and development on the natural, recreational and cultural resources of the Hudson River estuary. Attention has been directed particularly to projects in the early stages of planning that ultimately could be sited on the Hudson River. Considerable public opinion has favored the adoption of land use planning and controls as means of averting or minimizing potential problems.

3.14 Accomplishments along these lines constitute important elements of a comprehensive land use strategy. Legislative initiatives in New York have led to its being one of the nation's strongest authorities over matters of land use (U.S. Council on Environmental Quality, 1976). Laws provide, among other things, for the protection of wetlands, designation of environmentally fragile and historically significant areas, and participation by the State in management programs authorized by the Coastal Zone Management Act of 1972. In addition, the laws impose several requirements on the State's electrical utility companies, including requirements to disclose long-term generation and transmission plans and to identify sites held for future expansion.

3.15 Notwithstanding the statutory power of the State, much of the authority to formulate policies on growth and to regulate development remains vested in local government. Although land use plans have been developed for all of the counties on the Hudson River estuary, many with the aid of funds made available by the State of New York or through the Comprehensive Planning Assistance Program authorized by Section 701 of the Federal Housing Act of 1954, evidence of coordination at a regional level is fragmented. In the case of counties on the lower estuary--Hudson and Bergen Counties in New Jersey; the boroughs of New York City; and Rockland, Westchester, Putman, Organge, Dutchess and Ulster Counties in New York--the land use plans of individual counties have been integrated by the Tri-State Regional Planning Commission into comprehensive guidelines for regional development. Established initially as the Tri-State Regional Planning Commission by agreement among the governors of New York, New Jersey and Connecticut, the interstate agency now coordinates the goals and plans of 22 counties or boroughs in New York and New Jersey and six planning regions in southwest Connecticut under provisions of legislation in all three states. Through efforts to develop tools for cross-acceptance of regional and subregional land use plants, the Commission has successfully formulated and ensured a degree of consistency in the regional development guide covering the greater New York metropolitan area.

3.16 Growth in counties of the mid-Hudson region (Orange, Putnam, Dutchess, Ulster, Sullivan, Greene and Columbia Counties) has been the subject of extensive study by Mid-Hudson Pattern, Inc., an independent nonprofit organization engaged in community planning, research and development. Established in 1965, its basic function is to provide government and private enterprise with technical, research and planning assistance to promote informed decisions on issues concerning the future development of the mid-Hudson. Generally broader in geographical scope, the Regional Plan Association is a second civic organization which, since its first charter as a committee of the Russell Sage Foundation in 1922, has concentrated its efforts on developing regional approaches to problems facing the greater New York City area. Other instances of coordinated planning to satisfy the varied needs of this populous region have been isolated and aimed primarily at specific targets such as waste water treatment, transportation systems, or upgrading of recreational facilities.

3.17 Recognition of the value of a coordinated planning, comprehensive in scope both with respect to geographical extent and diversity of human need, if reflected in the establishment of the

Hudson River Valley Commission by New York State Executive Law, Section 721. In the early 1960s the Commission was granted authority to review proposed projects within one mile of the Hudson River shore, or within two miles if visible from the river, to determine whether such projects would destroy or substantially impair significant historic or recreational resources or cause major changes in the appearance or use of water.

3.18 While in the early stages of construction, the Bowline Point Generating Station was subject to the Commission's review. The Commission expressed reservations regarding the visibility of the station and the architectural merit of the plant's structures and expressed uncertainty, in view of the paucity of data then available, regarding the plant's impact on the aquatic ecosystem of the Hudson River. Nonetheless, following a public hearing held in the Town of Haverstraw on 3 February 1970 and consideration of the costs and benefits associated with the project, the Commission concluded that the benefits outweighed the costs, and accordintly, that the project would not exert an unreasonably adverse effect on the scenic, natural and recreational resources of the Hudson River Valley.

3.19 The functions of the Hudson River Valley Commission have been transferred to the New York State Department of Environmental Conservation but without allocations for personnel or an operating budget. Several responsibilities mandated in the Commission's original charter, particularly those concerning planning of water and related land resources, are now within the purview of the Coastal Zone Management Program administered by the Division of Planning, New York Department of State. On the basis of procedures and criteria developed in the first year of the program study, the entire Hudson River estuary falls within the initial delineation of the Coastal Zone. The State has applied for (19 March 1976) and received a grant covering the second year of a 4-year planning period under the terms of Section 306 of the Coastal Zone Management Act of 1972. The Coastal Management Office intends to expand and refine the results of the first year program and to perform additional required work.

3.20 Much of the second year grant will be suballocated to local governments to support their coastal zone management planning interests. Where matters of statewide, regional or intermunicipal concerns are noted, the State's Coastal Zone Management Program will identify the specific means for resolving differences, where these exist. Public participation will be significantly increased during the second year. In addition to the New York Department of State, participants in the program will include local governments, regional planning boards, the New York Department of Environmental Conservation and the New York Sea Grant Institute. Primary objectives will include giving clear, accurate information on the nature and scope of the Coastal Zone Management Program to the public, expanding and refining methods to obtain adequate levels of input from various public and private sources, and establishing a workable path from private interests through local and regional agencies to a statewide management program. The Coastal Zone Management Program thus provides an opportunity for State, local governments and the public to work collaboratively in promoting a wise and effective use of coastal zone resources. A management plan is due to be released to the public and submitted to the Federal Coastal Zone Management Office for approval in the fall of 1977. It is expected that the plan will include guidelines and criteria related to the siting of future energy facilities along the Hudson River.

3.21 A second comprehensive program is currently underway to evaluate the water resources of the entire Hudson River Basin. The 2-year Level B study sponsored by the Water Resources Council will draw on the input of several Federal, State and local governmental agencies to assess the adequacy of available resources in meeting anticipated needs and to address potential problems resulting from conflicting water and related land uses. As major consumers and users of water, existing and future power plants along the Hudson River will constitute one of the study's points of scrutiny.

Status? of study? completed?

3.22 Through a comprehensive assessment of the needs of communities on the Hudson River estuary and the carrying capacity of its varied resources, these ongoing studies undoubtedly will shed light on the complex issues that surround the siting of power plants. Until regionwide development options and recommendations are formulated, however, an understanding of the of the relationship between power generating facilities and land use on the estuary can be only rudimentary.

3.23 The Bowline Point Generating Station is not unique inasmuch as it conforms to the traditional proactice of locating a power plant in proximity to the load centers it serves, on a site with adequate water resources to supply the plant's cooling requirements and capable of accommodating modest expansion. Alternative trends in siting are emerging. Among these are the concept of clustering facilities in power parks and a growing tendency to locate power facilities in power parks and a growing tendency to locate power plants in remote, sparsely populated areas and transporting energy over increasingly long distances. Such strategies may or may not prove beneficial in terms of land use on the Hudson River estuary. Clearly, the Bowline Point and Roseton Generating Stations neither establish nor reinforce similar departures from the conventional approach to power plant siting.

CHAPTER 4

ENVIRONMENTAL IMPACTS OF THE PROJECT

4.01 The potential environmental impacts associated with the Bowline Point Generating Station and the cumulative impacts resulting from the operation of all of the existing generating facilities on the Hudson River estuary are presented in this section. Impacts on the physical, biological and human resources of the study area are analyzed in terms of the predominantly localized effects attributable to the operation of the Bowline Point and Roseton generating stations and the aggregated effects of present and future developments. Where appropriate, the analysis encompasses impacts that are regional in character and may be experienced beyond the limits of the study area.

4.02 All of the generating stations on the Hudson River presently operate with once-through condenser cooling systems. Requirements to install closed-cycle cooling at the Bowline Point, Roseton and Indian Point (Units 2 and 3) have been imposed by the U.S. Environmental Protection Agency. These requirements, in all instances, are being contested and are the subject of presently on-going adjudicatory hearings before the Agency (Appendix B).

update to current Status re Settlement Agreement.

IMPACTS ON PHYSICAL RESOURCES

4.03 The operation of the Bowline Point Generating Station and other steam electric facilities on the Hudson River estuary represents a potential source of impact on the physical resources of the study area. Concern centers principally on the rejection of waste heat to the river and the release of contaminants in airborne emissions and waterborne effluents. Potential effects on the physical environment include the alteration of the temperature and flow regime of the Hudson River estuary and the deterioration of ambient air and water quality. Delivery of fuel oil to the fossil fueled plant involves a risk of major spills and poses a further threat to the water resource.

Thermal Regime of the Hudson River Estuary

4.04 The characteristics of the thermal discharges from the Bowline Point Generating Station and the Roseton-Danskammer stations, as well as the combined thermal discharges from all of the existing and proposed power plants on the Hudson River estuary, have been studied extensively through mathematical modeling and computer simulations (Appendix E). The principal objective of the analysis is to determine under which conditions applicable water quality standards relating to thermal discharges could be exceeded.

New York State Criteria Governing Thermal Discharges

4.05 New York criteria governing thermal discharges (6NYCRR704) to estuaries or portions of estuaries provide that:

(1) The water temperature at the surface of an estuary shall not be raised to more than 90 F at any point.

(2) At least 50 percent of the cross sectional area and/or volume of the flow of the estuary, including a minimum of one-third of the surface as measured from water's edge to water's edge at any stage of tide, shall not be raised to more than 4 F over the temperature that existed before the addition of heat of artificial origin or a maximum of 83 F, whichever is less.

(3) From July through September, if the water temperature at the surface of an estuary before the addition of heat of artificial origin is more than 83 F, an increase in temperature not to exceed 1.5 F at any point of the estuarine passageway as delineated above, may be permitted.

(4) At least 50 percent of the cross-sectional area and/or volume of the flow of the estuary including a minimum of one-third of the surface as measured from water's edge to water's edge at any stage of tide, shall not be lowered more than 4 F from the temperature that existed immediately prior to such lowering.

4.06 Consideration of the provision that surface temperatures not exceed 90 F necessitates a detailed analysis of the behavior of the thermal plumes in the immediate vicinity of the Bowline Point and Roseton discharge diffusers. Analytical techniques are available to determine the levels of dilution in the near-field zones and the reduction in temperature of the discharge through mixing with the receiving waters before it reaches the surface of the estuary. The results of the analysis are generally quoted in terms of dilution ratios. Given a dilution ratio, the surface temperature in the vicinity of a discharge can be computed if the temperature of the water at the power plant intake, the ambient temperature at the discharge, and the rise in temperature across the condenser are known.

4.07 Near-field analyses cannot take into account such longer range phenomena as the recirculation of cooling water from a plant's discharge to its intake or the cumulative thermal interactions of power plants on a common body of water. A study of these effects requires the application of far-field techniques. One-dimensional techniques generally yield a broad overview and indicate where a more detailed investigation might be warranted. A two-dimensional or near-field-far-field analysis then is needed to study the spatial variation of temperature or any other relevant parameter in sufficient detail.

The Hudson River Estuary

4.08 Hydraulic and thermal analyses of the Hudson River estuary are rendered complex by the reversals in flow due to tidal action. Under conditions of reversing flow, the phenomena of reentrainment (the ambient water diluting a discharge is at an elevated temperature as a result of receiving the discharge or a separate thermal discharge at an earlier tidal phase) recirculation through a power plant and alternating multiplant interactions become important considerations. The locations of the thermal plumes change continuously in large portions of the river and quasi steady-state thermal conditions may be attained only after numerous flow-reversal periods. Field surveys are difficult to conduct under these conditions since an accurate representation of temperature over a substantial portion of the river would require deployment of a large number of boats, personnel, and equipment.

4.09 Further, a determination of whether a particular thermal discharge causes certain regulatory criteria to be exceeded is rendered difficult by the presence and possible influence of other discharges to the river. The New York State Criteria refer both explicity and implicity to conditions that prevail or would prevail in the absence of a thermal load of artificial origin. Without reversing flows, natural temperatures are generally a fair representation of the undisturbed conditions in the river. If the flow reverses periodically, on the other hand, natural temperatures can be determined only by field measurements taken at "reasonable distances" either upstream or downstream of the plant. The situation on the Hudson River is such that the zones of thermal influence about existing power plants overlap, making it impossible to ascertain through measurements alone the degree to which natural conditions are altered by each individual plant.

True?
or just more
difficult

Local Thermal Analysis at the Bowline Point and Roseton Generating Stations

4.10 The local dilution characteristics of the thermal discharge from the Bowline Point station (near-field analysis) have been examined on the basis of numerical simulations and available field data (Appendix E). The analyses show that (surface) dilution ratios for the Bowline Point diffuser vary from approximately 2 to a maximum of 6 (Appendix E). Values in the low end of the range apply when flow in the river is predominantly parallel to the diffuser, that is, under conditions close to flood tide. The higher values apply at or near ebb tide and high slack water. Since the temperature rise across the power plant condenser is nominally 15 F, an excess temperature of 7.5 F at the surface near the diffuser could be experienced under worst case conditions.

4.11 Dilution ratios for the Roseton diffuser are estimated to range from 3 to 6 (Appendix E). Thus, with a temperature rise of 18 F across the condensers of the Roseton station, the maximum excess surface temperature in its vicinity would be 6 F. The near-field analysis also indicates that the thermal plume from the Danskammer Generating Station at plant loads below 60 percent of rated capacity does not penetrate the Roseton discharge area. With the Danskammer plant operating above this power level, the thermal plumes overlap, and predictions of the maximum surface temperatures that result cannot be made by means of near-field simulations.

Analysis of Cumulative Impacts of all Generating Stations

4.12 The overall thermal effect of power plant operations on the entire Hudson River estuary (far-field analysis) has been assessed through the application of a tidal-transient computer simulation model. All the important natural and power plant induced effects that can influence the thermal conditions in the estuary are considered in the model and its associated computer code ESTONE. The model is one of the general one-dimensional "Unified Transport Approach" models being developed specifically to assess the thermal, chemical, radiological, and biological impacts that operating power plants exert on the aquatic ecology of large receiving water bodies. Details of computer model are given in the Draft EIS (Appendix E) and in Appendix E of this report.

Was it ever completed.

4.13 The far-field analysis of the Hudson River estuary focuses on the 6-month portion of the year from 1 April through 30 September. This period is considered the most critical with respect to the life cycle of the striped bass and certain other fishes of the Hudson River. Further, the highest natural temperatures in the estuary prevail within this period and the possibility is greatest that the thermal discharges from the power plants would give rise to temperatures in excess of regulatory criteria. Data collected in 1973 and 1974 underlie the analysis. Information relating to the physical conditions of the river (freshwater flow, tidal conditions, atmospheric conditions and so on) is used both to validate the model and to assess the thermal effects due to power plants. Operational information on the power plants is used to predict temperature

What about more recent data?

distributions in the estuary on the basis of physical conditions prevailing in 1964 (a drought year) and 1974 (a year of more typical flow).

4.14 For modeling purposes, the Hudson River estuary from the Federal dam at Troy to the Battery (152 miles) is divided in 76 discrete elements, each 2 miles in length. Numerical solutions of the equations incorporated in ESTONE are derived in time steps of 0.0625 hours. The computed results are stored at every 16-time step interval, providing a temperal resolution of 1-hour over the 6-month simulation period. Daily-average conditions are derived from hourly values. Computational details of the model are given in the Draft EIS, Appendix E, Section 3.4.2, and in Appendix E of this Final EIS.

4.15 Results of the Far-Field Analysis for 1974 Conditions. Several cases are considered in the analysis to evaluate the thermal effects associated with each power plant and their cumulative effects on the estuary (See Draft EIS, Appendix E, Section 3.4.5.2). These cases are:

- Case 1 - "Clean River." This case establishes the conditions that would have prevailed in 1974 if no artificial heat load had been imposed on the river by any power plants. The results provide a baseline or point of reference to compare the results of the analysis to regulatory criteria that relate to natural conditions.
- Case 2 - 1974 Conditions. Data collected in 1974 are used to simulate the effects of power plant operating during that year.
- Case 3 - Proposed Maximum Thermal Load Conditions. Operation of all existing power plants at full rated capacity and with once-through cooling, and the proposed Greene County nuclear power plant with closed-cycle cooling is considered.
- Case 4 - Full Once-Through Thermal Load Conditions. The simulation relates to the full power operation of existing power plants, and the proposed Greene County plant, all with once-through cooling.
- Case 5 - Clean River with Only Roseton and Danskammer Power Plants. This simulation yields an estimate of the contribution of the Roseton and Danskammer stations to the thermal loading of the river.

not logical

If these are factored in, then cumulative flow augmentation loads had been factored in as well and along with that of the Chelsea pumping Station.

- Case 6 - Clean River with Only the Bowline Point Power Plant. This simulation yields an estimate of the contribution of the Bowline Point Generating Station to the thermal loading on the river.

What Happened to the Lovett Station?

- Case 7 - Proposed Maximum Thermal Load (as in Case 3) Except Bowline Point Station Point with Closed-Cycle Cooling. A comparison with the results of Case 3 provides an estimate of the reduction in the thermal loading of the estuary that would result from the installation of closed-cycle cooling at the Bowline Point station only.

- Case 8 - Proposed Maximum Thermal Load (as in Case 3) Except Indian Point Power Plant with Closed-Cycle Cooling. A comparison with the results of Case 3 provides an estimate of the reduction in the thermal loading of the estuary that would result from the installation of closed-cycle cooling at the Indian Point station only.

4.16 The results of the simulations show that water temperatures in excess of the regulatory criterion of 83 F could occur under physical conditions similar to those prevailing in 1974 (see Table 3.4.13 in Appendix E of the Draft EIS). Predicted excesses occur in the 2-mile segment of the river in the vicinity of Indian Point and are all less than 1 F in magnitude. Maximum temperatures of 83.80, 83.87 and 83.42 F are predicted in Cases 3, 4 and 7, respectively. The last of these indicate that the 83 F criterion would be exceeded under proposed maximum thermal load conditions, regardless of whether or not a closed-cycle cooling system is installed at the Bowline Point station. The maximum temperature that would occur in the critical 2-mile segment without an artificial heat load (clean river conditions) is predicted to be 80.49 F. The contribution from the Bowline Point and the Roseton-Danskammer stations would raise this maximum by 0.4 and 0.3 F, respectively.

4.17 More specifically, the results of the simulations, based on the physical conditions prevailing in the estuary in 1974 and daily-averaged, cross section-averaged and (2-mile) segment-averaged temperatures, are:

(1) Under proposed maximum thermal loading of the river (Case 3, all existing power plants with open-cycle cooling, Greene County plant with closed-cycle cooling), the regulatory criterion limiting temperature increases to 4 F above natural conditions would not be exceeded.

(2) Under full once-through cooling load (Case 4) the same 4 F regulatory criterion would not be exceeded.

(3) Under Case 3 conditions, the regulatory criterion limiting the maximum temperature over 50 percent of the cross-sectional area of the river to 83 F would be exceeded.

(4) Under Case 4 conditions, the same 83 F regulatory criterion would be exceeded.

(5) Conditions prevailing under Case 3 would not be alleviated by the installation of closed-cycle at the Bowline Point station alone to the point where the same 83 F regulatory criterion would be met.

(6) Conditions prevailing under Case 3 would be alleviated by the installation of closed-cycle cooling at Indian Point stations alone to the point where the same 83 F regulatory criterion would be met.

both units?

(7) Operation of the Greene County nuclear station with once-through cooling instead of the proposed closed-cycle cooling would not appreciably raise the temperature in the critical 2-mile segment of the river between Bowline Point and Indian River.

4.18 In summary, the far-field analysis for 1974 conditions indicates that the thermal conditions in the Hudson River estuary, with the existing configuration of power plants and the configuration expected in the near future and under typical physical conditions of the river at the warmest times of the year are very close to the limitations stipulated by New York State thermal criteria.

4.19 Near-Field-Far-Field Analysis of 1974 Conditions. On the basis of findings of the far-field thermal analysis, a 10-mile section of the Hudson River along which the Indian Point, Lovett and Bowline Point stations are located, has been selected for detailed analysis (Draft EIS, Appendix E, Section 3.5). A systematic zone-matching methodology is applied to study the two-dimensional (with results integrated over depth) temperature distributions in the vicinity of the Bowline Point, Indian Point and Lovett stations. The analysis relates to Case 3; namely, operation of all existing power plants at full rated capacity and with once-through cooling and the proposed Greene County nuclear power plant with closed-cycle cooling.

not in the 11 mile zone?

4.20 The results of the near-field-far-field analysis in the vicinity of the Bowline Point station indicate that certain New York State regulatory criteria would be exceeded occasionally. Specific findings based on the river conditions of 4 August 1974 (Draft EIS, Appendix E, Section 6.1.3) are:

> Critical thermal conditions in the Hudson River in the vicinity of the Bowline Point station will occur generally during the afternoon and evening hours, between 13:00 and 22:00 hours, on various days in July and August. Operation of the station gives rise to temperatures in the river in excess of regulatory standards by virtue of (a) the occurrence of surface temperatures in excess of 91 F (90 F limit), (b) the occurrence of temperatures of 84 F (83 F limit) over one-third of the surface as measured from water's edge, and (c) the occurrence of temperatures of 84 F (83 F limit) over 50 percent of the cross-sectional area or volume of the flow of the estuary.

4.21 Results applicable to the thermal distribution in the Hudson River in the vicinity of the Indian Point station, again based on natural conditions prevailing on 4 August 1974, are:

> Critical thermal conditions will occur generally during the afternoon and evening hours between 1300 and 2200 hours on various days in July and August. Operation of the Indian Point station with once-through cooling will give rise to temperatures in excess of regulatory standards by virtue of (a) the occurrence of surface temperatures of 84 F (83 F limit) at the surface of the river from water's edge to water's edge (limit of one-third of the surface) and (b) the occurrence of temperatures of 84 F (83 F limit) over 100 percent of the cross-sectional area or volume of flow (50 percent limit).

4.22 Results of the Far-Field Analysis for 1964 Conditions. In response to comments received on the Draft EIS, a far-field computer analysis has been carried out for the low-flow drought conditions of 1964. Because ~~the proposed~~ Greene County power plant has been cancelled since the publication of the Draft EIS, this power plant was removed from the model runs for the 1964 conditions. Results of the model runs are given in Appendix E.

why was it included in the 1974 run?

Three cases have been considered:

- Case 1 - "Clean River." This case establishes the conditions that would have prevailed in 1964 if no artificial heat load had been imposed on the river by the operation of any power plants. The results provide a baseline or point of reference to compare the results of the analysis to regulatory criteria.

- Case 2 - Rated Load. Operation of all existing power plants at 90 percent of rated capacity with once-through cooling.

- Case 3 - Projected Load. Operation of the Bowline Point, Indian Point, Lovett, Danskammer, and Roseton stations at power levels projected to be typical averages in the future (projected power levels supplied by the Utilities). The power level for Indian Point, Albany Steam Station and 59th Street Power Plant were set at 90 percent of rated capacity. All power plants were simulated with once-through cooling.

4.23 The computer simulation results for the longitudinal distributions of water temperature conditions along the estuary for the projected load and rated load cases were compared with the "clean river" case to determine the far-field thermal impact of multi-power-plant operation on the Hudson River during the six-month period 1 April - 30 September 1964. Since the computer simulations were begun on 1 April 1964, the month of April was not included in the considerations of the far-field thermal analysis because quasi-steady state thermal conditions were not reached during one month. Therefore, the computer simulation results for the longitudinal distributions of water temperature conditions along the estuary were considered for the period 15 June - 30 September 1964.

4.24 Simulation results were calculated for:

- daily-averaged, cross-section-averaged water temperature
- daily-maximum, cross-section-averaged water temperature
- daily-averaged surface water temperature
- daily-maximum surface water temperature

The results were presented graphically as

- longitudinal distributions of water temperature conditions along the estuary on midmonth and endmonth days during 15 June - 30 September 1964.
- daily variations of the local water temperature conditions at Indian Point (model element 55) and Bowline Point (model element 58) during the six-month period.

4.25 Examination of the computer simulation of longitudinal temperature distribution along the Hudson River indicates that the greatest effect of power plant operations under 1964 river flow conditions occurs in the portion of the river between Bowline Point and Indian Point, which is effected by the discharge from those plants as well as the Lovett station. Simulation results also indicate that New York State standards governing thermal discharges would be violated in this reach of the river by operation of the power plants with once-through cooling under 1964 river flow conditions.

4.26 With respect to the temperature standard specifying a maximum water temperature increase of 4F when the natural river temperature is less than 83F, violations occurred only under the Rated Load case near Indian Point for three to eight day periods during June and September. Violations were slight, however, with 4.4F being the greatest temperature increase occurring. Violations of this magnitude would be within the error limits of the model. No violations occurred under the Projected Load case.

4.27 Violations of the criterion restricting the maximum water temperature increase to 83F occurred for estimated periods of 9 to 40 days during June, July, and August near Indian Point and Bowline Point. Violations occurred under both the Projected Load and Rated Load cases.

4.28 Violations of the criterion limiting maximum water temperature increases to 1.5F when natural river temperatures are greater than 83F occurred near Indian Point and Bowline Point under both the Projected and Rated Load cases. Violations for estimated periods of 10 to 30 days occurred near Indian Point during June, July, and August. A violation occurred during an estimated 10 day period in late July and early August near Bowline Point.

Summary Conclusions of Thermal Analysis

4.29 The following general conclusions may be drawn from the overall thermohydraulic analysis of the Hudson River Estuary:

(1) During years of normal river flow, water temperatures in the river will occasionally and under certain natural conditions exceed applicable New York State standards as a result of the operation of all existing plants at full power and with open-cycle cooling.

(2) During drought years, water temperatures in the river will exceed New York State standards as a result of the operation of all existing plants with open-cycle cooling and at average power level less than full rated power.

(3) Maximum temperatures will occur in the vicinity of the Bowline Point, Lovett and Indian Point stations.

(4) Use of cooling towers at Indian Point would have the greatest effect on reducing water temperatures in the region of the river between Bowline Point and Indian Point.

(5) Excesses in temperature over regulatory criteria are not inordinate under normal flow conditions, but increase with decreasing flow of fresh water in the river as would occur during drought years.

Flow Regime of the Hudson River Estuary

4.30 Although the direct consumption of water at the Bowline Point Generating Station and at other generating stations on the Hudson River estuary is small, the heat load imposed on the river by the operating power plants promotes evaporation at a rate greater than would naturally prevail and effectively results in a consumptive use of the water resource. The rate at which additional losses of water are incurred is determined by a large number of factors, including the characteristics of the thermal plume and prevailing meteorological conditions. The U.S. Environmental Protection Agency estimates that, as a general rule, the rate of evaporation of water associated with a once-through cooling system is 1/2 to 2/3 the rate of evaporation from a mechanical draft evaporative cooling system in comparable service (39 FR 36193, 8 October 1974). Assuming further that 75 percent of the heat rejection from a mechanical draft system is effected through the mechanisms of evaporation, the evaporative losses associated with the Bowline Point station amount to an estimated 7 to 12 cubic feet per second (computed at a latent heat of evaporation of water of 970.3 BTU per pound at 1.0 atmospheres and 77°F).

4.31 Upper estimates of the water losses resulting from the operation of all the existing power plants on the Hudson River estuary with open cycle cooling are:

GENERATING STATION	HEAT REJECTION RATE (Billion Btus per hour)	WATER LOSSES Cubic Feet Per Second	WATER LOSSES Million Gallons Per Day
Fifty-ninth Street	0.34	0.8	0.52
Bowline	5.17	12	7.8
Lovett	2.38	5.5	3.6
Indian Point	13.3	30	19
Roseton	5.92	14	9
Danskammer	2.97	6.8	4.4
Albany	9.82	4.2	2.7
TOTAL	31.9	73	47

4.32 The total estimated losses of the order of 70 cubic feet per second are small in comparison to the average annual flow of 13,000 cubic feet per second gaged at Green Island (National Commission on Water Quality, 1975). It may be well to note that the flow at Green Island represents the major portion but not the entire flow of fresh water into the lower Hudson River. As indicated previously, the oscillating tidal flow in the estuary can exceed the flow of freshwater by a factor of 10 to 100, making these losses of even lesser significance when the rejection of waste heat gives rise to the evaporation of brackish or saline water.

4.33 In terms of the flow regime of the lower Hudson River, the evaporative losses of water caused by the rejection of waste heat from existing power plants are considered to be negligible. The same conclusion is expected to hold true if and when closed cycle cooling systems are installed at the Bowline Point station and other eligible power plants in accordance with the requirements of 40 CFR 423. Evaporative consumption at those plants is then expected to be 1.5 to 2 times the values given above. Clearly, however, there would be a limit to the additional waste heat from future steam electric stations that could be accommodated without appreciably affecting the movement of the salfront or other hydrologic characteristics of the river or substantially depleting the freshwater resource.

Water Quality

4.34 The operation of the Bowline Point Generating Station and other generating stations on the Hudson River estuary is a potential cause of degradation in the quality of the receiving waters as a result of the discharge of heat, residual quantities of chlorine in the cooling water, and contaminants in the various liquid waste effluents from the power plants. Liquid wastes are discharged in controlled amounts both during normal operations and during periods when the power plants are shut down for maintenance. Limitations are imposed on the properties of the discharges by the National Pollutant Discharge Elimination System permits authorizing the discharge of liquid wastes from each of the stations. Further, these limitations reflect "the degree of effluent reduction attainable by the application of best available technology economically achievable" (40 CFR 423) at the Bowline Point and Roseton generating stations and other eligible facilities, as required by the Water Pollution Control Act Amendments of 1972 (PL 92-500).

Bowline Generating Station

4.35 Liquid effluents from the Bowline Point Generating Station meet all the limitations imposed by the current National Pollutant Discharge Elimination System Permit (Appendix B) issued to Orange and Rockland by the U.S. Environmental Protection Agency, authorizing the discharge of liquid wastes from the station. Ongoing surveys at Bowline Point show that water quality is not being affected measurably and that applicable water quality standards established by the State of New York are not being violated as a result of the operation of the plant. A summary of the principal characteristics of waterborne effluents from the Bowline Point Station is given in Table 4-1. A more detailed discussion of waterborne waste streams from Bowline is given in Appendix D.

4.36 Discharge of Chemical Compounds and Sanitary Wastes. Releases of chemical compounds associated with the operation of Bowline generating station are primarily those stemming from boiler blowdown. Estimates indicate that residual quantities of chemical compounds present in the blowdown will occur in receiving waters in maximum concentrations ranging from 0.01 and 0.25 milligrams per liter (Orange and Rockland, 1974a). While some of the chemical compounds that might be discharged in the blowdown from the Bowline Point boilers (hydrazine, disodium phosphate, sodium hydroxide, sodium sulfite and cyclohexylamine) and certain derivatives of these compounds are known to be toxic to aquatic life (U.S. Atomic Energy Commission, 1973), there are no reports of toxic effects associated with such contaminants at concentrations likely to be encountered in the Hudson River as a result of the discharges from the Bowline Point Station.

Sanitary wastes from Bowline are discharged to the Haverstraw municipal sewage system.

TABLE 4-1

CHARACTERISTICS OF WATERBORNE EFFLUENTS FROM THE BOWLINE POINT GENERATING STATION

WASTE STREAM	DISCHARGE			PRINCIPAL CHARACTERISTICS OF THE DISCHARGE		
	FREQUENCY	RATE	DISPOSAL	PROPERTIES		EFFLUENT LIMITATIONS IMPOSED BY NPDES PERMIT
Condenser cooling water	Continuous	768,000 gallons per minute	Hudson River	Heat addition rate:	5.6 billion Btu per hour	5.8 billion Btu per hour
				Maximum temperature:	93.5F	102F
				Temperature rise:	13.5F	23F
				Free available chlorine:	0.1 milligrams per liter, maximum	0.2 milligrams per liter maximum, 48.5 pounds per day
				Chlorination schedule:	Occasional, as required; suspended when water temperature is below 50F	Chlorination suspended when water temperature is below 50F
				pH:	Ambient river	6.0 to 9.0 or 0.2 pH units valuation from intake
				Velocity at travelling screens:		0.77 feet per second maximum daily average
				Oil and greese:	None added	None discharged
				Soils:	None added	No deposition or deleterios effects
				Ambient standards in receiving waters:	Applicable New York State standards	Applicable New York State standards
Boiler blowdown	Once daily	121,000 gallons	Hudson River	Trace quantities of:	Hydrazine, sodium sulfite, disodium phosphate, sodium hydroxide, cyclohexylamine	All limitations applicable to condenser cooling water
				pH:	8.0 to 9.5	
Prefilter backwash, water treatment system	Once weekly	10,500 gallons per wash	Hudson River	Suspended solids:	Filtered from municipal water supply	All limitations applicable to condenser cooling water
Service water strainer backwash	Twice weekly	9,000 gallons per wash	Hudson River	Suspended solids:	Accumulated river debris	All limitations applicable to condenser cooling water
Air preheater washdown	Once quarterly	1,800 gallons per wash	Hudson River	Solids:	Suspended and dissolved products of oil combustion	All limitations applicable to condenser cooling water
				pH:	Acidity increases from 3.5 to 7 during each washdown	
Boiler seal trough	Continuous	15 gallons per minute	Hudson River	Solids:	Ash	All limitations applicable to condenser cooling water
Demineralizers regeneration, water treatment system	Once every 3 days	17,000 gallons per regeneration	Municipal sewage treatment plant	Solids:	Dissolved sodium sulphate mineral salts suspended micro-sized particles	None Applicable
				pH:	Neutral	
Boiler cleaning wastes	Once yearly	-	Off site	-	-	None applicable
Plant laboratory wastes	Intermittent	-	Municipal sewage treatment plant	-	-	None applicable
Sanitary wastes	Intermittent	-	Municipal sewage treatment plant	-	-	None applicable
Stormwater runoff from oil storage are	Intermittent	-	Minisceongo Creek to Hudson River	Oil and grease:		15 milligrams per liter average, 20 milligrams per liter maximum
--------------------						
Cooling tower blowdown	Continuous	6,600 gallons per minute	Hudson River	Heat addition rate:	0.06 Btu per hour	0.090 billiong Btu per hour October through May, 0.015 billion Btu per hour June through September
				Maximum blowdown temperature:	99F	99F
				Toxic wastes and deleterious substances	No discharge	No discharge

4.37 Surface Runoff. Stormwater runoff from roofs, yards, roadways and parking lots is discharged to Minisceongo Creek and the Hudson River through the station drainage system. Runoff from the fuel storage facility is collected in a 2,000 gallon sump. Collected stormwater is monitored by means of an oil detector and, in most circumstances, is processed by an oil-water separator even when the concentration of oil is below the limit stipulated in the National Pollutant Discharge Elimination System permit (a maximum concentration of 20 milligrams per liter of oil and grease and a daily average concentration of 15 milligrams per liter). Following exceptionally heavy precipitation, the processing may be suspended if monitoring indicates that the discharge would meet the regulatory limitations. Waste oil recovered from the separator is collected periodically for disposal by a commercial waste contractor. Degradation of Hudson River water quality from these sources will be small compared to the magnitude of other waste streams entering the river.

4.38 Chlorination. Chlorination is not needed at Bowline on a regular schedule. When chlorine is added, predictions (Orange and Rockland, 1974) indicate that residual quantities of free available chlorine at concentrations of 0.1 milligrams per liter diluted further in the receiving waters and reduced in time through chemical reactions and atmospheric losses, should not be toxic to aquatic organisms.

4.39 Ambient Water Quality in Receiving Waters. Surveys of water quality have been in progress in the vicinity of Bowline and Lovett generating stations since 1971 (Orange and Rockland, 1974a; 1975; 1976). Measurements of approximately 30 standard water quality parameters have been made once a month since mid-June 1973. A summary of data on selected parameters observed during 1974 and 1975 together with pertinent details of the sampling program are given in Appendix D.

4.40 Several years of water quality monitoring of the Hudson River in the vicinity of Bowline Point confirm the results of predictive analyses and preliminary conclusions of earlier, less complete surveys, namely that the waterborne discharges from the Bowline Point station cause no measurable degradation in the quality of the receiving waters of the Hudson River. Apart from temperature, there are no observations that would indicate a change in any of the monitored parameters attributable directly or indirectly to the operation of the Bowline Point station.

4.41 Dissolved oxygen at the plant discharge is generally equal to or greater than that measured at the other sampling stations, implying that the circulating water system does not directly lower or adversely affect the level of dissolved oxygen in the river. The observed monthly values follow the well known seasonal trend of decreasing dissolved oxygen levels with increasing ambient river temperatures, reaching a low point of the order of 6 milligrams per liter in midsummer and a high 13 milligrams per liter in winter. Sample values below 5.0 milligrams per liter (the applicable New York State standard) have been observed. Extreme low readings of 4.8 milligrams per liter in the Bowline Point Channel and 4.5 milligrams per liter in Bowline Pond are recorded for 1974 and 1975, respectively, and are probably a result of eutrophic conditions in the river.

4.42 Observed pH values show no marked differences in the measurements made at each of the stations. The pH is relatively constant throughout the year with an average value of approximately 7.5. The extreme range of pH in the individual observations made in the 2-year period is 6.8 to 8.0.

4.43 The ongoing survey in the vicinity of Bowline Point confirms the fact that the waters of the lower Hudson River are rich in nutrients. Measured values of total nitrogen (nitrates plus Kjeldahl nitrogen) and total phosphorus are of the order of 1 milligram per liter and 0.1 milligram per liter, respectively, both indicative of a eutrophic system (U.S. Council on Environmental Quality, 1976). Occasional low values of dissolved oxygen occur naturally in such systems. While the eutrophic conditions in the river cannot be related to the operation of the Bowline Point Generating Station, these are the most likely cause of the infrequent observations of dissolved oxygen values below 5.0 milligrams per liter.

4.44 Yearly average measurements of fecal coliforms at the four sampling stations ranged approximately between 600 and 1,500 cells per 100 milliliters in 1974 and between 450 and 1,400 counts per 100 milliliters in 1975. Measurements on individual samples exhibit much larger variations with observations ranging as high as 5,000 to 8,000 cells per 100 milliliters. The average levels are generally lower than a geometric mean of 2,000 cells per 100 milliliters recommended for public water supplies (U.S. Environmental Protection Agency, 1973), but higher than 200 cells per 100 milliliters considered desirable in bathing waters (U.S. Council on Environmental Quality, 1976; U.S. Environmental Protection Agency, 1976).

4.45 Among the heavy metals monitored in the vicinity of Bowline Point and Lovett Generating Stations, chromium and lead were not found in 1975 at levels above 0.10 and 0.08 milligrams per liter, respectively, the limits of detectability of the particular methods employed in the survey (Orange and Rockland, 1976). Observed concentrations of zinc ranged from values less than 0.10 milligram per liter to 0.29 milligram per liter and concentrations of iron ranged from values less than 0.03 to 3.53 milligrams per liter, with a yearly average of approximately 0.65 milligram per liter.

4.46 Impact on Ambient Water Quality. Waterborne discharges from the Bowline Point Generating Station to the Hudson River are made into waters classified by the State of New York as SB or suitable for bathing and other usages except shellfishing for market purposes (Parts 700-703, Title 6, Official Compilation of Codes, Rules and Regulations, New York State). Applicable standards for Class SB waters are the following:

Items	Specification
Floating solids; settleable solids; oil; sludge deposits; solids	None attributable to sewage, industrial wastes or other wastes
Garbage, cinders, ashes, oils, sludge or other refuse	None in any waters of the marine district as defined by State Conservation law
Sewage or waste effluents	None which are not effectively disinfected
Dissolved oxygen	Not less than 5.0 parts per million
Toxic wastes, deleterious substances, colored or other wastes or heated liquids	None alone or in combination with other substances or wastes in sufficient amounts or at such temperatures as to be injurious to edible fish or shellfish or the culture or propagation thereof, or which in any manner shall adversely affect the flavor, color, odor or sanitary condition thereof; and otherwise none in sufficient amount to make the waters unsafe or unsuitable for bathing or impair the waters for any other best usage as determined for the specific waters which are assigned to this class

4.47 The liquid effluents from the station currently lead to no violation of applicable water quality standards. Individual water samples taken in the vicinity of the station indicate that the dissolved oxygen level occasionally and locally drops below the regulatory limit of 5.0 parts per million. This phenomenon may be attributed to the eutrophic conditions of the Hudson River.

4.48 It is anticipated that the liquid effluents from a closed-cycle cooling system installed at the Bowline Point Station would reflect the application of the best available technology economically achievable (40 CFR 423.13) and, similarly, would not lead to violations of water quality standards in receiving waters.

Roseton Generating Station

4.49 Data on the use of chemical compounds at the Roseton generating station are available only for 1974, a year of partial operation of only one unit (Appendix D). All chemical discharges will meet the requirements of National Pollution Discharge Elimination System permit authorizing the discharge of liquid wastes from the Roseton Generating Station. Operational data are not yet available to assess the effect of chemical discharges on the estuary in the vicinity of Roseton, but preoperational monitoring data have found no effects attributable to discharges from the nearby Danskammer plant. No effects are likely from the Roseton discharge.

True?

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4.50 Chlorination. Chlorination has not been used on a regular schedule at Roseton since the early weeks of operation. When added, dosage is the maximum quantity that can be added without exceeding the limit of 0.5 milligrams per liter free chlorine residual required by New York State water quality standards.

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4.51 Ambient River Water Quality. Available data does not include the period of regular operation of the Roseton power units. Several years of preoperational monitoring data in the vicinity has found no changes in water quality attributable to the operation of the nearby Danskammer power plant. Waterborne discharges from the Roseton facility are, likewise, not expected to alter ambient river conditions as they presently exist.

Cumulative Impacts

4.52 The liquid effluents from the Roseton generating station (Central Hudson, 1975) and other steam electric facilities on the Hudson River estuary contain residuals of chlorine, oil and grease, combustion products, and a variety of chemical contaminants. In addition, liquid effluents from the Indian Point Generating Station contain traces of radioactive substances (U.S. Environmental Protection Agency, 1974). The quantities of contaminants released to the river are small and are required to conform to applicable effluent limitation standards established by the U.S. Environmental Protection Agency (40 CFR 423) and design objectives of the U.S. Nuclear Regulatory Commission (10 CFR 50, Appendix I).

4.53 Both the tidal and freshwater flow of the Hudson River are generally several orders of magnitude greater than the flow of liquid discharges from individual plants, providing the potential of diluting waste material to extremely low concentrations. The behavior of contaminants in such circumstances is not well understood, and there are no techniques available to predict the transport and fate of the contaminants and their possible derivatives. While several mechanisms, such as sedimentation, bioaccumulation and chemical interactions could, in principle, lead to substantive cumulative effects, there are at present no indications of potential problems resulting from the operation of power plants on the Hudson River.

4.54 Problems relating to water quality in the lower Hudson River stem principally from the release of nutrients and organic matter from municipal sewage treatment systems, with industrial releases contributing to the organic load (National Commission on Water Quality, 1976). The attendant conditions of low levels of dissolved oxygen and high counts of coliform bacteria are expected to improve markedly by 1985 when the goal of eliminating discharges, expressed in the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500), is realized. It is anticipated that remaining difficulties with respect to water quality will then be associated with the relatively high content of coliform bacteria and heavy metals in urban runoff as well as small contributions of nutrients, pesticides and other contaminants in the storm runoff from nonurban areas (National Commission on Water Quality, 1976). While the relative contribution of power plants to water quality degradation may rise from its present low level, it is expected to remain small or negligible and confined to the release of trace contaminants.

4.55 Water quality surveys to date indicate that no measurable reductions in the dissolved oxygen content of the Hudson River waters occur as a result of thermal discharges from power plants. More detailed field measurements, particularly under less eutrophic conditions in the receiving waters, might reveal a demonstrable reduction in dissolved oxygen within the thermal plumes associated with the discharges. However, hazardously low (to aquatic life) levels of dissolved oxygen are currently absent outside of the Albany and New York City portions of the estuary, and it may be anticipated that the continued operation of existing facilities with once-through cooling would not lead to a significant cumulative lowering of dissolved oxygen in the river waters. From the standpoint of dissolved oxygen, additional heat rejection loads from future power plants ~~might be~~ tolerable, provided interactions ~~among thermal plumes can be avoided~~. The installation of closed-cycle cooling at all eligible existing plants and future power plants effectively eliminates the possibility of a significant lowering of the dissolved oxygen content of the Hudson River waters.

will be tolerable

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Air Quality

4.56 The releases of airborne contaminants from the Bowline Point and Roseton Generating Stations and other fossil fueled stations within the study area is subject to state regulations governing the composition and use of fuels in stationary combustion installations. New York State regulations (6 NYCRR, Parts 225, 227) limit the permissible content of sulfur in fuel oil burned at the Fifty-Ninth Street, Bowline Point and Lovett stations to 0.37 percent by weight and to 2.0 percent by weight in fuel burned at the Roseton, Danskammer (changed to 1.0 percent on 1 August 1976) and Albany stations. The ash content of all fuel oil is required to be sufficiently low to limit emissions of particulate matter to a maximum rate of 0.10 pounds per million BTU heat input, averaged over 2 hours. Emission rates of nitrogen oxides are limited to 0.30 pound per million BTU heat input.

4.57 Field measurements of air quality in the vicinity of the Bowline Point Generating Station have shown that New York Ambient Air Quality Standards (6 NYCRR, Parts 256, 257) for particulates, sulfur dioxide and nitrogen dioxide have not been exceeded as a result of operating the power plant.

4.58 Monitoring data taken in 1975 and early 1976 in the vicinity of the Roseton Generating Station indicate that the New York State hourly* and 24-hour standards** for sulfur dioxide were being exceeded occasionally. All other applicable state standards

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*An hourly standard for sulfur dioxide was in effect at the time of writing. The hourly standard has been rescinded (6 NYCRR, Part 257, effective 18 March 1977) in New York State.

**The 24-hour New York State standard for sulfur dioxide requires that the 24-hour concentration not exceed 0.14 part per million and also that 99 percent of 24-hour values during 12 consecutive months not exceed 0.10 part per million. Observations near the Roseton facility show that only the first provision of the standard is being exceeded occasionally.

for sulfur dioxide, particulates and nitrogen dioxide were being met. Observations from several stations within the Roseton monitoring network indicated that the Federal secondary standard for suspended particulates (24-hour concentration) was being exceeded occasionally. Central Hudson reports that, since 1 August 1976 when the sulfur content of the fuel oil burned at the Danskammer power plant was reduced from 2.0 to 1.0 percent, compliance with the New York 24-hour standard for sulfur dioxide has been achieved.

4.59 The possibility has been examined that airborne emissions from the Roseton and Danskammer stations might act cumulatively with emissions from the Bowline Point and Lovett stations to produce undesirably high concentrations of sulfur oxides (Appendix E). The results of a numerical simulation show no evidence that annual average concentrations of sulfur dioxide at ground level approach Federal standards (Appendix E of the DEIS, Section 4.3.3). The Albany and 59th Street stations are considered to be too far removed from the other stations in the study area to contribute appreciably to cumulative concentrations of sulfur oxides at ground level.

4.60 The operation of evaporative cooling towers at fossil fueled stations within the study area introduces the potential for interactions among the plumes from stacks and cooling towers, with the consequent formation of acidic mists. Knowledge of the physical and chemical phenomena in merged plumes is incomplete and a precise assessment of the attendant risk of affecting air quality or producing adverse effects at ground level cannot be made. Information available to date indicates that impacts resulting from plume interaction at the Bowline Point and Roseton stations, or other stations on the Hudson River Estuary, would not be appreciable (Appendix E, Section 4.3.5).

Air Quality at Bowline Point

4.61 Numerical simulations (Orange and Rockland, 1971; 1972; 1973), carried out before the Bowline Point Generating Station was put into operation, indicated that certain New York State ambient air quality standards could be exceeded as a result of operating the power plant. The analyses showed that both hourly* and 24-hour average limitations on sulfur dioxide concentrations would be exceeded on the ridge line (High Tor ridge) and peak areas to the southwest of the station during periods of stable atmospheric conditions and moderate winds.

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*The hourly standard for sulfur dioxide concentration is no longer in effect in New York State.

4.62 Orange and Rockland instituted a program to monitor pertinent meteorological and air quality parameters at several monitoring stations in the vicinity of the site both before and after the initial operation of the Bowline Point units. Three stations were located on the High Tor ridge where the concentrations of sulfur dioxide were expected to be the highest under certain meteorological conditions.

4.63 In addition, Orange and Rockland sponsored a measurement program to observe the behavior of the plumes from the Bowline Point station stacks using fluorescent particle tracers injected into the stack (Orange and Rockland, 1976). Five sets of observations were made on three separate days between 19 January and 31 July 1976 when meteorological conditions were predicted to be most conducive to direct contact of High Tor by the plume. On each of these occasions, the prevailing combination of wind speed and atmospheric stability were such that the plume was located above the ridge and no direct contact occurred. Further, the time averaged dilution, or dispersion of the plume was sufficiently great to prevent the concentration of sulfur dioxide on the ridge from exceeding ambient standards. An examination of meteorological data gathered at the Bowline Point station between August 1972 and April 1976 shows no instance when conditions of wind and stability would lead to the fumigation of High Tor ridge, and the possibility of the critical combination of meteorological factors occurring is taken to be remote on the basis of both the available ovservation and meteorological records.

4.64 Annual reports summarizing the results of meteorological and air quality measurements from June 1974 to May 1975 (Orange and Rockland, 1975) and and June 1975 to May 1976 (Orange and Rockland, 1976) have been prepared and filed with the New York State Department of Environmental Conservation. No instances of state air quality standards being exceeded have been reported to date (Burns, 1976).

4.65 The possibility of burning less expensive fuel oil with a sulfur content greater than 0.37 percent by weight has been investigated (Orange and Rockland, 1976). Numerical simulations practical fuel switching program involving fuel oils with sulfur contents of 0.37 and 2.2 percent. Orange and Rockland has applied to indicate that ambient air quality standards can be maintained under a the New York State Department of Environmental Conservation for authorization to implement the fuel switching program.

4.66 Air Quality Monitoring. Air quality monitoring in the vicinity of the Bowline Point station region began in 1970. Observations were made at various times between 1 May 1970 and 31 August 1972 to establish baseline conditions before Unit 1 was put into commercial service (Orange and Rockland, 1973). Measurements of the ambient concentrations of sulfur oxide and particulates were made at four locations in the Haverstraw area, the primary location being the office building of the Rockland County Health Department in Haverstraw. Measurements of nitrogen oxides concentrations were made at one site only, the New York State Rehabilitation Hospital. Early analysis of measurements showed that data from the various monitoring stations could be combined to yield a reasonable representation of air quality in the general vicinity of the power plant (Orange and Rockland, 1973a).

4.67 Summary results of preoperational air quality monitoring are given in Tables 4-2 and 4-3. The principal findings, based on data given in these tables as well as cumulative probability distribution developed from measurements of nitrogen oxide concentrations over a 6-month period, are as follows:

(1) Prevailing concentrations of sulfur dioxide were substantially below New York State air quality standards. Observed hourly average concentrations reached 25 percent of standards, while daily and annual averages reached 50 percent of the respective standards.

(2) Observed concentrations of particulates ranged in value from levels corresponding to 70 percent of standards to values in excess of these standards.

(3) Average 24-hour concentrations of nitrogen oxides would exceed the ambient standards of 0.05 parts per million roughly 64 percent of the time during a period of 12 consecutive months. Further, correlations of air quality and meteorological observations indicated that all three airborne contaminants, observed routinely in high concentrations, were not of local origin. The data suggested that airborne contaminants migrated from the southeast across Haverstraw Bay and, from the southwest, from the Ramapo, Mawah and Hackensack River Valleys.

4.68 A monitoring program designed to measure sulfur dioxide concentrations attributable to the operation of the Bowline Point station was instituted in March 1972 in response to the stipulations of the New York Department of Environmental Conservation. A network of six real-time (continuous) stations was established in the vicinity of the station at points identified in Figure 4-1. Provisions have been made to monitor concentrations of particulate matter and nitrogen dioxide at three of the stations. Pertinent characteristics of the network are given in Table 4-4.

TABLE 4-2

SUMMARY OF PREOPERATIONAL OBSERVATIONS OF SULFUR DIOXIDE CONCENTRATIONS AT BOWLINE POINT

	OBSERVED CONCENTRATIONS IN PARTS PER MILLION		NEW YORK STANDARDS IN PARTS PER MILLION	
PERIOD	99 PERCENT FREQUENCY	MAXIMUM OBSERVED	99 PERCENT FREQUENCY	MAXIMUM OBSERVED
1-Hour Average Concentration*				
1 May 70–31 Aug 72	0.058	0.128	0.25	0.50
1 Sep 70–31 Aug 71	0.069	0.128	0.25	0.50
1 Sep 70–31 Aug 72	0.047	0.096	0.25	0.50
Summers	0.053	0.100	0.25	0.50
Winters	0.068	0.128	0.25	0.50
24-Hour Average Concentration				
1 May 70–31 Aug 72	0.051	0.070	0.10	0.14
1 Sep 70–31 Aug 71	0.057	0.070	0.10	0.14
1 Sep 71–31 Aug 72	0.037	0.04	0.10	0.14
Summers	0.035	0.052	0.10	0.14
Winters	0.057	0.070	0.10	0.14
ANNUAL AVERAGE		OBSERVED		AVERAGE
1 May 70–31 Aug 72		0.0158		0.030
1 Sep 70–31 Aug 71		0.0172		0.030
1 Sep 71–31 Aug 72		0.0141		0.030

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*Hourly standard for sulfur dioxide concentration is no longer in effect in New York State.

Source: Orange and Rockland, March 1973a.

TABLE 4-3

SUMMARY OF PREOPERATIONAL OBSERVATIONS OF TOTAL SUSPENDED PARTICULATE CONCENTRATIONS AT BOWLINE POINT

STATION	CONCENTRATION OF PARTICULATES IN MICROGRAMS PER CUBIC METER		NEW YORK STANDARDS IN MICROGRAMS PER CUBIC METER
	HI-VOLUME EQUIVALENT	HI-VOLUME SAMPLE	
50 PERCENT FREQUENCY			
Health Department Bldg.	58	73	65
Bowline Point Tower	65.5	-	65
Health Department Bldg. and Bowline Point Tower	62	73	65
84 PERCENT FREQUENCY			
Health Department Bldg.	85	96	100
Bowline Point Tower	92	-	100
Health Department Bldg. and Bowline Point Tower	87	96	100
100 PERCENT FREQUENCY			
Health Department Bldg.	199.7	124	250
Bowline Point Tower	218.5	178	250
Health Department Bldg. and Bowline Point Tower	218.5	178	250

Source: Orange and Rockland, March 1973a.

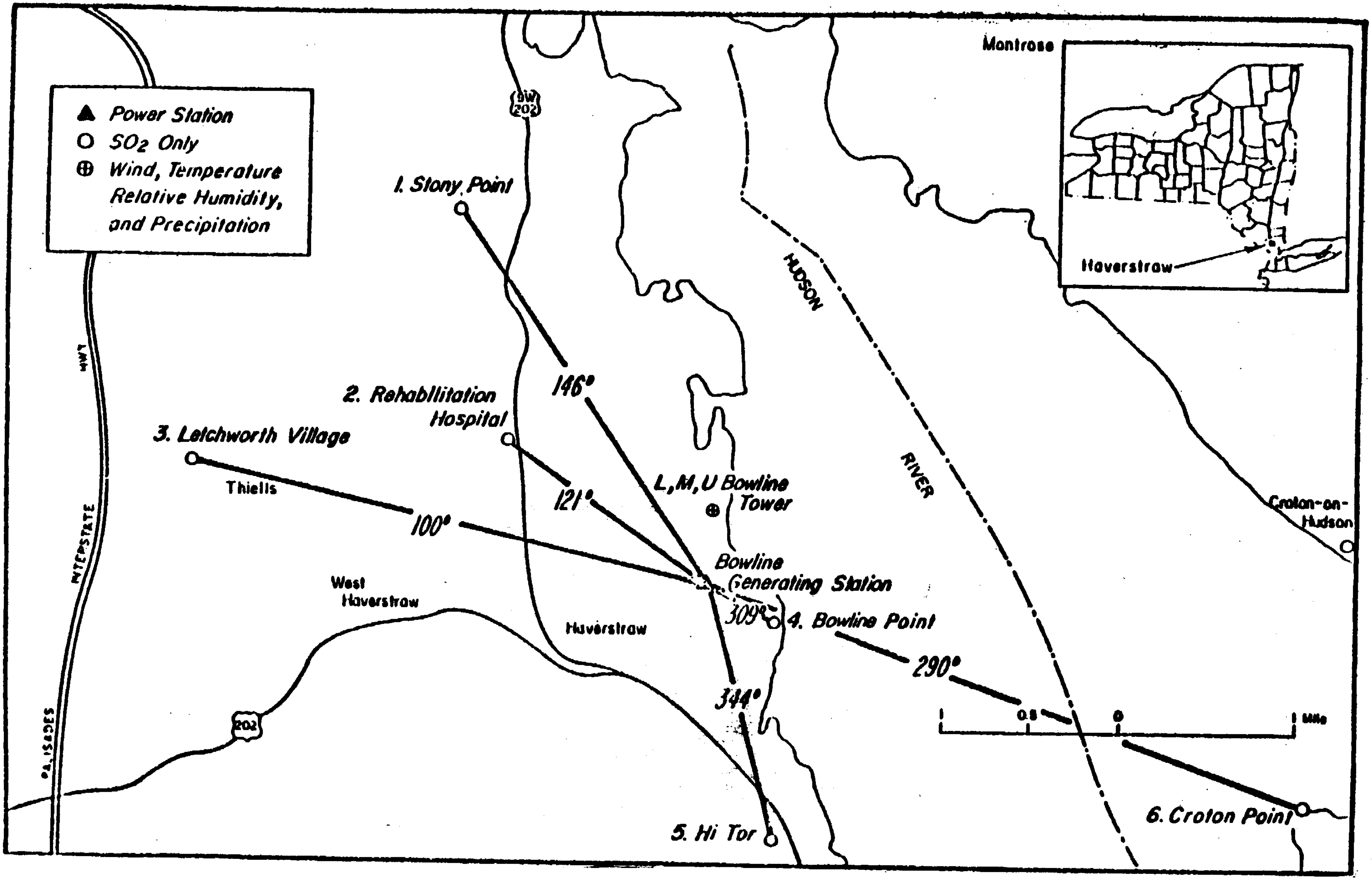

FIGURE 4-1
HAVERSTRAW, NEW YORK AIR MONITORING NETWORK (Directions indicated are those of winds that would blow from the plant towards the monitoring stations).

TABLE 4-4

CHARACTERISTICS OF THE AIR QUALITY MONITORING NETWORK AT BOWLINE POINT

STATION NUMBER	STATION	ELEVATION,(1) FEET	DOWNWIND SECTOR,(2) DEGREES	DISTANCE FROM POWER PLANT, MILES
1	Stony Point	220	116-176	2.6
2	Rehabilitation Hospital	180	91-151	1.4
3	Letchworth Village	450	70-130	3.1
4	Bowline Point	8	279-339	0.5
5	Hi Tor	564	314-014	1.5
6	Croton Point	62	260-320	3.8

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(1) Feet above mean sea level. The top of the stacks at the Bowline Point Generating Station is 287 feet above ground level and 297 feet above mean sea level.

(2) The downwind sector is the sector ± 30 degrees from the wind direction that places the station downwind of the power plant; angles are measured clockwise from a reference of due north at 0° or 360°.

Source: Orange and Rockland, July 1976.

4.69 Quarterly and yearly reports documenting the results of field measurements have been prepared since the inception of the monitoring program. The latest available annual report (Orange and Rockland, 1976) contains data pertaining to sulfur dioxide measurements from June 1975 to May 1976. A summary of the measured average daily concentrations is given in Table 4-5. The data show no instance of the ambient standard of 0.1 part per million being exceeded during the period under consideration.

4.70 Summaries of results derived from measurements of nitrogen dioxide concentrations (from June to November 1974 and March to May 1975) and particulate concentrations (September 1974 to November 1974 and December 1974 to May 1975) are given in Tables 4-6 and 4-7. The observed concentrations of nitrogen dioxide measured hourly and averaged monthly are generally well below 0.05 part per million, with monthly averages approaching this value only occasionally. Accordingly, it appears unlikley that the standard of 0.05 part per million, applicable to observations taken over 12 consecutive months will be exceeded. Maximum hourly measurements of nitrogen dioxide concentrations are substantially higher and occasionally reach values of the order of 0.6 part per million. Data on concentrations of particulates show no instance of state standards being exceeded during the monitoring period.

4.71 Measured concentrations of nitrogen dioxide taken after the Bowline Point station became operational, therefore, differ substantively from the preoperational concentrations discussed previously. The later information shows that lower concentrations prevail, suggesting either a reduction in background levels or deficiencies in one or both sets of measurements. No data are available from alternative sources to indicate the more likely explanation for the apparent discrepancy.

Air Quality at the Roseton Generating Station

4.72 An air quality monitoring network has been established in the vicinity of the Roseton and Danskammer generating stations. The individual stations making up the network are identified in Figure 4-2 and pertinent information on the station is given in Table 4-8.

4.73 Summaries of data collected over the 12-month period from March 1975 through February 1976 are given in Tables 4-9, 4-10, and 4-11 (data on sulfur dioxide concentrations) and Tables 4-12 and 4-13 (data on total suspended particulate and nitrogen oxide concentrations, respectively). Measurements of sulfur dioxide concentrations indicate that 99 percent of hourly average values are below the New

TABLE 4-5

SUMMARY OF SULFUR DIOXIDE OBSERVATIONS AT BOWLINE POINT, JUNE 1975 THROUGH MAY 1976

MONTH	NUMBER OF DAYS WITH AVERAGE DAILY CONCENTRATIONS IN EXCESS OF 0.10 PARTS PER MILLION/NUMBER OF DAYS OF OBSERVATIONS					
	STONY POINT	REHABILITATION HOSPITAL	LETCHWORTH VILLAGE	BOWLINE POINT	HI TOR	CROTON POINT
1975						
June	0/18	0/29	0/30	0/30	0/21	0/30
July	0/30	0/22	0/30	0/29	0/27	0/30
August	0/31	0/23	0/31	0/31	0/31	0/31
September	0/30	0/30	0/30	0/30	0/30	0/30
October	0/31	0/30	0/31	0/30	0/31	0/28
November	0/29	0/30	0/30	0/19	0/30	0/28
December	0/30	0/28	0/28	0/31	0/31	0/28
1976						
January	0/31	0/25	0/31	0/31	0/30	0/30
February	0/29	0/23	0/29	0/27	0/28	0/29
March	0/31	0/31	0/26	0/31	0/23	0/29
April	0/28	0/30	0/29	0/30	0/30	0/30
May	0/31	0/14	0/31	0/28	0/31	0/31

Source: Orange and Rockland, July 1976.

TABLE 4-6

SUMMARY OF NITROGEN DIOXIDE LEVELS AT BOWLINE POINT, JUNE 1974 THROUGH MAY 1975.

STATION	MONTH AND YEAR	DATA CAPTURE, PERCENT	NITROGEN DIOXIDE CONCENTRATIONS, PARTS PER MILLION	
			MAXIMUM HOURLY	MONTHLY AVERAGE
STONY POINT	Jun 74	79	0.033	0.005
	Jul 74	50	0.030	NA
	Sep 74	95	0.180	0.049
	Oct 74	97	0.155	0.030
	Nov 74	61	0.194	NA
	Mar 75	100	0.094	0.021
	Apr 75	98	0.125	0.038
	May 75	100	0.116	0.038
LETCHWORTH VILLAGE	Jun 74	53	0.146	NA
	Jul 74	100	0.095	0.022
	Aug 74	100	0.084	0.027
	Sep 74	100	0.116	0.027
	Oct 74	100	0.155	0.031
	Nov 74	100	0.133	0.030
	Mar 75	99	0.107	0.026
	Apr 75	99	0.150	0.023
	May 75	99	0.165	0.046
HI TOR	Jun 74	27	0.088	NA
	Sep 74	84	0.103	0.022
	Oct 74	90	0.166	0.037
	Nov 74	700	0.164	0.030
	Mar 75	99	0.095	0.025
	Apr 75	98	0.458	0.044
	May 75	98	0.568	0.044

Sources: Orange and Rockland, November 1974; February 1975; July 1975.

TABLE 4-7

SUMMARY OF TOTAL SUSPENDED PARTICULATE OBSERVATIONS AT BOWLINE POINT, SEPTEMBER 1974 THROUGH MAY 1975

	TOTAL SUSPENDED PARTICULATE CONCENTRATIONS IN MICROGRAMS PER CUBIC METER, EXCEPT AS NOTED		
PERIOD	STONY POINT	LETCHWORTH VILLAGE	WEST HAVERSTRAW SUBSTATION
<u>SEPTEMBER 1974-NOVEMBER 1974</u>			
Data capture, percent	84.6	69.2	85.7
Computed geometric mean	31.3	35.9	36.2
Computed standard deviation	2.0	1.8	1.7
Number of excesses of:(1)			
24-hour N.Y. State standard	0	0	0
24-hour Federal primary standard	0	0	0
24-hour Federal secondary standard	1	0	0
<u>DECEMBER 1974-MAY 1975</u>			
Data capture, percent	93.4	76.4	91.8
Computed geometric mean	32.6	46.5	47.0
Computed standard deviation	1.8	1.7	1.6
Number of excesses of:(1)			
24-hour N.Y. State standard	0	0	0
24-hour Federal primary standard	0	0	0
24-hour Federal secondary standard	0	1	0

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(1) The Federal standards are values not to be exceeded more than once a year. New York State standards, until 18 March 1977, were maximum values.

Source: Orange and Rockland, November 1974; February 1975; July 1975.

1974

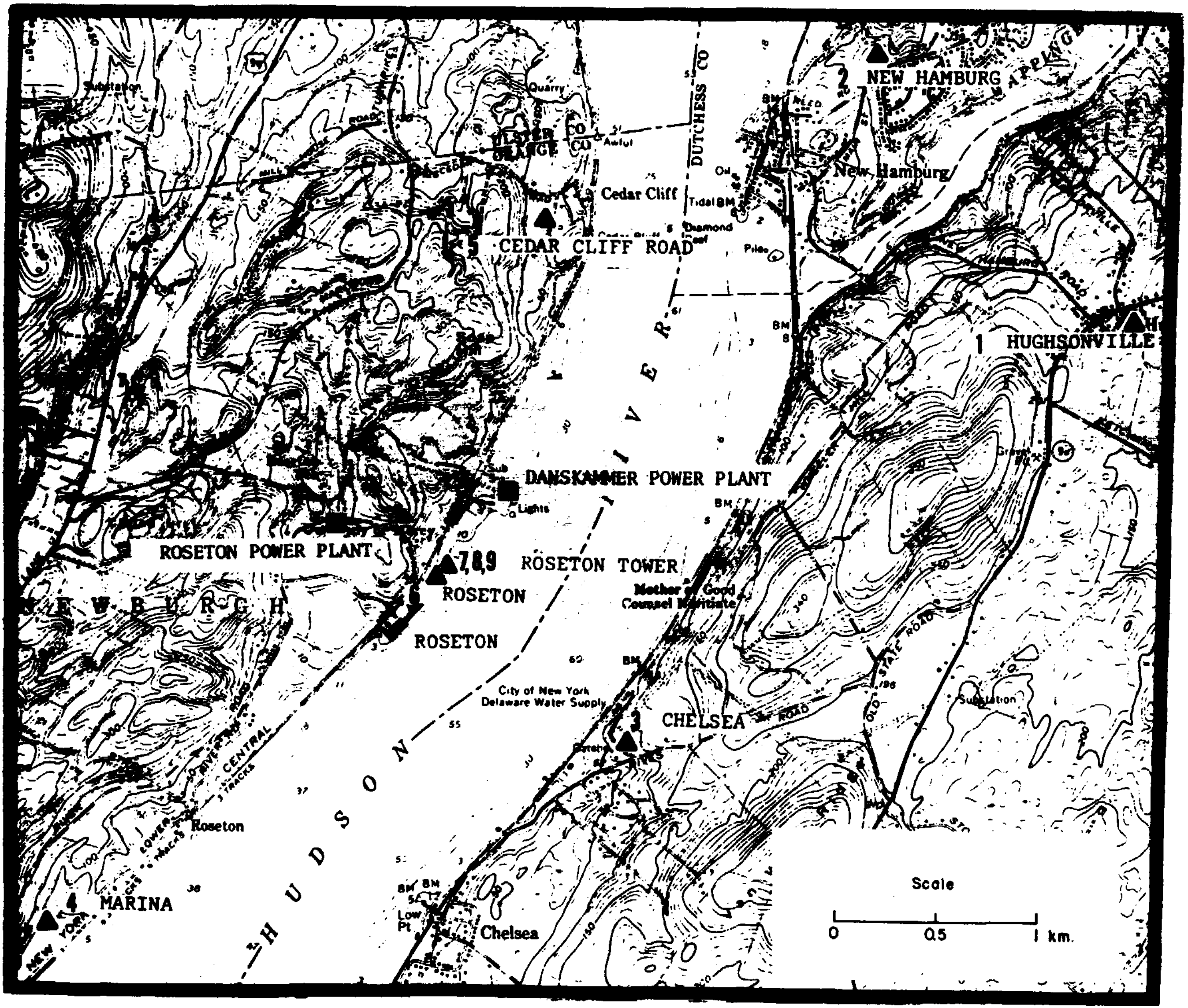

FIGURE 4-2
MONITORING NETWORK FOR THE DANSKAMMER AND ROSETON POWER PLANTS

TABLE 4-8

CHARACTERISTICS OF THE AIR QUALITY MONITORING NETWORK AT THE ROSETON STATION

STATION NUMBER	STATION	ELEVATION FEET (1)	DOWNWIND SECTOR, (2) DEGREES		DISTANCE FROM POWER PLANTS, MILES
			FROM DANSKAMMER	FROM ROSETON	
1	Hughsonville	132	225-285	226-286	2.1-2.5
2	New Hamburg	122	190-250	199-259	1.7-2.2
3	Chelsea	83	304-004	277-337	0.9-1.1
4	Marina	8	017-077	006-066	1.9-1.6
5	Cedar Cliff Road	115	157-217	183-243	0.9-1.1
A	Wheeler Hill Road	325	255-315	245-305	1.0-1.6
6	Roseton	6	009-069	266-326	0.4-0.3

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(1) Feet above mean sea level.

(2) The downwind direction is the direction of a wind that places the station downwind of the power plant. The downwind sector is subtended by an arc ± 30 degrees centered on the downwind direction. Angles are measured clockwise from North at 0°.

Source: Central Hudson, June 1976.

TABLE 4-9

SUMMARY OF HOURLY SULFUR DIOXIDE OBSERVATIONS AT ROSETON STATION, MARCH 1975 THROUGH FEBRUARY 1976

STATION	OBSERVED HOURLY CONCENTRATIONS OF SULFUR DIOXIDE ABOVE 0.25 PARTS PER MILLION					
				NET GENERATION, MW		
	DATE	TIME	WIND DIRECTION,(1) DEGREES	DANSKAMMER	ROSETON	SULFUR DIOXIDE HOURLY CONCENTRATION, PARTS PER MILLION
1. Hughsonville	5 Jul 75	0900	173	317	399	0.436
	5 Sep 75	1000	175	310	561	0.314
2. New Hamburg	9 Aug 75	1200	177	376	574	0.296
	3 Oct 75	2100	199	383	572	0.283
	8 Oct 75	1200	122	176	852	0.352
	28 Feb 76	0900	229	307	568	0.263
3. Chelsea	8 Mar 75	1600	305	203	1,006	0.267
	26 Mar 75	1600	307	181	1,030	0.291
	26 Mar 75	1800	311	175	1,032	0.291
	4 Apr 75	1000	305	188	1,010	0.281
	4 Apr 75	1100	306	186	1,011	0.266
	4 Apr 75	1300	302	201	1,012	0.306
	4 Apr 75	1400	307	192	1,013	0.265
	4 Apr 75	1600	299	193	1,010	0.333
	4 Apr 75	1700	297	196	1,010	0.358
	30 Jul 75	0900	150	250	930	0.375
4. Marina	31 Dec 75	2200	31	235	284	0.344
	31 Dec 75	2300	29	233	286	0.294
	1 Jan 76	0000	33	233	284	0.319

TABLE 4-9
(Continued)

	OBSERVED HOURLY CONCENTRATIONS OF SULFUR DIOXIDE ABOVE 0.25 PARTS PER MILLION					
				NET GENERATION, MW		
	DATE	TIME	WIND DIRECTION,(1) DEGREES	DANSKAMMER	ROSETON	SULFUR DIOXIDE HOURLY CONCENTRATION PARTS PER MILLION
5. Cedar Cliff Road	16 Mar 75	1100	129	137	926	0.281
	19 Apr 75	1200	214	151	1,017	0.450
	12 Jun 75	1000	184	343	530	0.285
	23 Jun 75	0200	205	218	546	0.257
	23 Jun 75	0300	209	193	448	0.425
	23 Jun 75	0400	209	187	495	0.375
	23 Jun 75	0500	211	197	550	0.581
	11 Sep 75	2100	176	312	573	0.338
	11 Sep 75	2200	178	284	548	0.304
	12 Sep 75	0100	177	224	298	0.309
	12 Sep 75	0200	174	209	296	0.371
	12 Sep 75	0300	176	207	297	0.443
	12 Sep 75	0400	176	209	297	0.412
	12 Sep 75	0500	177	209	318	0.304
	12 Sep 75	0600	181	223	391	0.253
	4 Oct 75	0400	196	124	455	0.271
	14 Oct 75	1400	195	186	955	0.496
	21 Nov 75	1100	181	338	264	0.306
	21 Nov 75	1200	179	325	266	0.379
	21 Nov 75	1300	184	324	268	0.275
	26 Nov 75	1500	016	361	200	0.261
A. Wheeler Hill Road	NO VALUES EXCEED 0.25 PARTS PER MILLION					

TABLE 4-9
(Concluded)

STATION	OBSERVED HOURLY CONCENTRATIONS OF SULFUR DIOXIDE ABOVE 0.25 PARTS PER MILLION					
	DATE	TIME	WIND DIRECTION,(1) DEGREES	NET GENERATION, MW		SULFUDIOXIDE HOURLY CONCENTRATION PARTS PER MILLION
				DANSKAMMER	ROSETON	
6. Roseton	5 Apr 75	0900	301	184	1,015	0.265
	5 Apr 75	1000	320	205	1,017	0.284
	5 Apr 75	1200	330	189	1,017	0.252
	5 Apr 75	1400	320	156	1,024	0.282
	5 Apr 75	1500	333	156	1,020	0.292
	21 Apr 75	1200	317	156	1,022	0.316
	26 Apr 75	1600	312	114	806	0.278
	30 Jul 75	0900	150	250	930	0.347

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(1) Wind direction measured at the upper level of the Roseton meteorological tower.

Source: Central Hudson, June 1976.

TABLE 4-10

SUMMARY OF 24-HOUR SULFUR DIOXIDE OBSERVATIONS AT ROSETON, MARCH 1975 THROUGH FEBRUARY 1976

OBSERVED 24-HOUR CONCENTRATIONS OF SULFUR DIOXIDE EXCEEDING 0.10 PARTS/MILLION

	STATION	DATE	STARTING HOUR	WIND DIRECTION,(1) DEGREES	AVERAGE GENERATION, MW		OBSERVED SULFUR DIOXIDE CONCENTRATIONS, PARTS/MILLION
					DANSKAMMER	ROSETON	
1.	Hughsonville		NO VALUES EXCEED 0.10 PARTS PER MILLION				
2.	New Hamburg		NO VALUES EXCEED 0.10 PARTS PER MILLION				
3.	Chelsea	8 Mar 75	0200	308	193	976	0.128
		26 Mar 75	1100	307	197	780	0.122
		3 Apr 75	1900	298	194	982	0.177
4.	Marina		NO VALUES EXCEED 0.10 PARTS PER MILLION				
5.	Cedar Cliff Road	22 Jun 75	1000	208	212	675	0.173
		23 Jun 75	0300	208	306	602	0.134
		11 Sep 75	2000	177	278	485	0.159
A.	Wheeler Hill Road		NO VALUES EXCEED 0.10 PARTS PER MILLION				
6.	Roseton	5 Apr 75	0600	322	167	957	0.166
		26 Apr 75	1300	313	120	952	0.103

(1) Wind direction is measured at the upper level of Roseton meteorological tower and is averaged over the period beginning 3 hours before and ending 3 hours after the hour of highest sulfur dioxide concentration within the 24-hour averaging period.

(2) Value is the 24-hour running average sulfur dioxide concentration.

Source: Central Hudson, June, 1976.

TABLE 4-11

SUMMARY OF MONTHLY SULFUR DIOXIDE CONCENTRATIONS AT ROSETON, MARCH 1975 THROUGH FEBRUARY 1976

STATION	AVERAGE MONTHLY CONCENTRATION OF SULFUR DIOXIDE, PARTS PER MILLION												
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	12-MONTH AVERAGE
1. Hughsonville	.014	.016	.013	.011	.010	.010	.009	.007	.015	(1)	-	-	.012
2. New Hamburg	.011	.009	.011	.006	.008	.013	.010	.018	.031	.025	.034	.026	.017
3. Chelsea	.031	.038	.013	(1)	.009	.008	.009	.016	.020	.022	.025	.017	.019
4. Marina	.016	.014	.013	.012	.011	.014	.010	.019	.021	.027	.039	.022	.018
5. Cedar Cliff Road	.015	.018	.026	.027	.020	.015	.017	.018	.027	.018	.025	.019	.020
A. Wheeler Hill Road	-	-	-	-	-	-	-	-	-	(1)	.015	(1)	.015
6. Roseton	.019	.033	.011	.008	.009	.010	.007	.010	.018	.019	.022	.017	.015
Average of Stations	.018	.021	.014	.013	.011	.012	.010	.015	.022	.022	.027	.020	.017

(1) Insufficient data to compute a valid average (≥ 480 hours of data per month, 2 months per season and all seasons for an annual computation are required

Source: Central Hudson, June 1976.

TABLE 4-12

SUMMARY OF 24-HOUR TOTAL SUSPENDED PARTICULATE OBSERVATIONS AT ROSETON MARCH 1975 THROUGH FEBRUARY 1976

STATION	OBSERVED 24-HOUR CONCENTRATIONS OF TOTAL SUSPENDED PARTICULATES EXCEEDING 150 MICROGRAMS PER CUBIC METER					
	DATE	PREVAILING WIND		AVERAGE GENERATION, MW		OBSERVED CONCENTRATIONS, MICROGRAMS PER CUBIC METER
		DIRECTION, DEGREES	SPEED, MPH	DANSKAMMER	ROSETON	
1. Hughsonville	1 Mar 75	308	6	196	844	160.0
	6 Mar 75	274	7	197	996	151.0
	17 Mar 75	14	9	166	912	184.0
	14 Apr 75	322	6	174	529	161.0
	21 May 75	279	4	159	927	189.0
	15 Aug 75	9	7	322	431	182.0
2. New Hamburg	6 Mar 75	274	7	197	996	151.0
	19 Jan 76	24	12	360	279	170.0
4. Marina	12 Apr 75	341	8	126	995	176.0
	20 May 75	198	9	161	884	163.0
	23 May 75	238	7	170	967	173.0
	29 May 75	182	5	163	748	182.0
5. Cedar Cliff Road	15 Apr 75	326	7	162	916	177.0

Source: Central Hudson, June 1976.

TABLE 4-13

COMPARISON OF TOTAL SUSPENDED PARTICULATE OBSERVATIONS AT ROSETON TO APPLICABLE NEW YORK STATE STANDARDS, MARCH 1975 THROUGH FEBRUARY 1976

STATION	PERCENT OF DAILY CONCENTRATIONS[1] OF TOTAL SUSPENDED PARTICULATES BELOW 50 PERCENT STANDARD[2]				PERCENT OF DAILY CONCENTRATIONS[1] OF TOTAL SUSPENDED PARTICULATES BELOW 84 PERCENT STANDARD[3]			
	SPRING	SUMMER	FALL	WINTER	SPRING	SUMMER	FALL	WINTER
1. Hughsonville	47.1	42.3	40.1	—	77.1	73.1	70.6	—
2. New Hamburg	61.6	63.6	65.1	64.1	89.5	88.8	86.9	85.4
3. Chelsea	76.0	76.6	78.8	79.3	96.0	94.6	94.0	98.8
4. Marina	67.1	75.6	79.5	81.2	91.1	92.4	93.5	98.8
5. Cedar Cliff Road	79.9	83.1	84.7	92.8	97.4	97.8	97.8	100.0
A. Wheeler Hill Road	—	—	—	86.1	—	—	—	100.0

[1] Cumulative to end of each quarter.

[2] New York State standards in effect before 18 March 1977 required that 50 percent of daily average concentrations of total suspended particulates be below 55 micrograms per cubic meter at stations 1, 2, 3 and 4 (Level II standard) and 65 micrograms per cubic meter at stations 4 and 5 (Level III). The requirement is no longer in effect.

[3] New York State standards in effect before 18 March 1977 required that 84 percent of daily average values be below 85 micrograms per cubic meter at stations 1, 2, 3 and 4 and 100 micrograms per cubic meter at stations 4 and 5. The requirement is no longer in effect.

Source: Central Hudson, June 1976.

York State standard of 0.25 part per million* (Central Hudson Gas and Electric, June 1976). Instances of measured values in excess of 0.25 parts per million are recorded in Table 4-10. Among these, one value of 0.581 parts per million, measured at Cedar Cliff Road on 23 June 1975 is in excess of the regulatory standard of 0.5 parts per million. More than 99 percent of the measured 24 hour concentrations are below the standard for 0.10 parts per million (Central Hudson Gas and Electric, 1976). As indicated in Table 4-11, a total of eight running averages over 24 hours has exceeded 0.10 parts per million, and among these four are in excess of the standard of 0.14 parts per million. The highest 24-hour average concentration recorded over the period is 0.177 parts per million. The monthly average concentrations given in Table 4-12 show that the annual standard of 0.03 parts per million is not exceeded.

4.74 Observed values of total suspended particulate concentrations and applicable state standards are compared in Table 4-13. As indicated, concentrations at one of the stations (Hughsonville) fail to meet standards relating to the distribution of daily average concentrations, both at the 50 and 84 percent levels.** However, the geometric mean of 24-hour concentrations measured at all the stations over 12 consecutive months is below the regulatory standard (Central Hudson Gas and Electric, 1976) and no single value above the standard of 250 micrograms per cubic meter has been observed. Recorded 24-hour averages in excess of 150 micrograms per cubic meter, the Federal secondary standard, are listed in Table 4-13; the highest recorded value is 189 micrograms per cubic meter. Operation of the Roseton and Danskammer generating stations is thought to have contributed to particulate concentrations during 2 of the 13 days with highest daily levels over the 12-month period ending in February 1976 (Central Hudson Gas and Electric, 1976).

4.75 Values of the measured concentrations of nitrogen oxides given in Table 4-14 show that the annual average concentration is below 0.05 parts per million at all reporting stations. The standard of 0.05 parts per million of nitrogen dioxide, therefore, is not exceeded. The extreme 24-hour concentrations recorded at certain stations are substantially higher than the annual average, with values ranging to 0.184 parts per million.

4.76 Available information on air quality monitoring in the vicinity of the Roseton station over the period March 1976 to August

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*The hourly standard for sulfur dioxide concentrations is no longer in effect in New York State.

**These requirements are no longer in effect.

TABLE 4-14

SUMMARY OF NITROGEN OXIDES OBSERVATIONS AT ROSETON, MARCH 1975 THROUGH FEBRUARY 1976

STATION	AVERAGE MONTHLY CONCENTRATIONS OF NITROGEN OXIDES, PARTS PER MILLION												
	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	12-MONTH AVERAGE
2. New Hamburg	.018	.013	.019	.007	.007	.010	.016	.023	.044	.044	.046	.041	.024
3. Chelsea	.014	.014	.017	(1)	(1)	.019	.019	(1)	.043	.044	.041	.030	.024
4. Marina	.022	.022	.037	.015	.016	(1)	(1)	.025	.034	.040	.040	.031	.028
5. Cedar Cliff Road	.012	.009	.043	.031	.027	.032	(1)	(1)	.037	.046	.049	(1)	.031
Highest 24-hr concentration	.079	.143	.118	.103	.090	.079	.066	.102	.194	.194	.169	.138	-
Station number recording highest 24-hr concentration	2	4	5	5	5	5	5	4	5	5	2	2	-
Prevailing wind direction on highest day, degrees	236	226	194(2)	204	140	73	202	191	202	202	022	202	-

(1) Insufficient data to compute a valid average (480 or more hours per month are required).

(2) A concentration of .118 parts per million was recorded twice at the same location in May 1975. On the second occasion the wind was variable.

Source: Central Hudson, June 1976.

1976 (Central Hudson Gas and Electric, 1976) shows that observations continue to be occasionally above applicable standards. Two instances of 24-hour sulfur dioxide concentrations in excess of 0.14 parts per million are recorded (on 27 April 1976 and 13 July 1976) both at the Wheeler Hill Road Station. However, Central Hudson reports that since 1 August 1976 when the sulfur content of fuel oil burned at the Danskammer power plant has been reduced from 2.0 to 1.0 percent by weight, compliance with the New York 24-hour standard for sulfur dioxide has been achieved. Measurements of total suspended particulate concentrations indicate that the state standards are being met. The Federal secondary standard has been exceeded on five separate occasions during the reporting period.

IMPACTS ON BIOLOGICAL RESOURCES

4.77 Operation of electric generating stations on the Hudson River estuary represents a potential source of impacts on the natural upland, wetland, and aquatic ecosystems of the region. Of greatest concern are the effects of the rejection of waste heat to the river and the destruction of small aquatic organisms that are drawn through the power plant condenser system in the cooling water (entrainment) or are killed on the screens used to strain the cooling water flow (impingement).

4.78 The ecology of the Hudson River estuary has been studied extensively over the past 20 years. Major studies have been sponsored by several utility companies, beginning in 1958 with research sponsored by Consolidated Edison to evaluate the impacts of radioisotopes releases by Indian Point Unit No. 1 on man and other biota.

4.79 As a result of the controversy involving the Cornwall Project in the mid-1960s, Consolidated Edison sponsored the Hudson River Fisheries Investigation from 1965-1968 through the Hudson River Policy and Technical Committee, New York Department of Environmental Conservation. Other consultants were starting ecological studies when construction on Indian Point No. 2 was begun in 1968. Raytheon Corporation carried out a series of studies from 1968 through 1971. New York University has ~~been~~ carry~~ing~~ed out studies on entrainment effects at the Indian Point Units 1 and 2 condensers as well as relating the effects of the cooling systems to population of aquatic organisms in the river. Lawler, Matusky, and Skelly Engineers has developed hydraulic thermal models as well as models related to the entrainment of striped bass eggs and larvae.

No longer participating

greater role than these, what about TI, EAI

4.80 Additional studies sponsored by utilities other than Consolidated Edison are being carried out on the Hudson River to assess the impacts of entrainment and impingement and related matters. Further, New York State Department of Environmental Conservation, through the U.S. Department of Commerce, has underway a 3-year striped bass tagging program to determine the contribution of the Hudson River striped bass to the Mid-Atlantic fishery. An Inter-Utility Coordinating Committee has been established to coordinate the efforts of several utilities conducting studies on the Hudson River.

completed?

4.81 Several factors have greatly hindered the effort to assess adequately the cumulative impacts of power generation activities along the Hudson river estuary during the preparation of the draft environmental statement. Primary among these was the lack of adequate synthesis of the considerable data that had been gathered. Too much important information was available only in annual data report form with little analysis for trends or insight into system structure and function that should emerge from multi-year data. Also, many

basis for this?

How, such as?

basis

important data apparently were available but had not been worked up into a form useful for consideration in decision-making. Recent publications prepared for the Utilities have helped to alleviate this problem (Orange and Rockland, 1977; Central Hudson Gas and Electric, 1977; Lawler, 1978).

what about Con Edison

way out of date

4.82 Contributing to the problem of data synthesis has been the fragmented research approach of considering individual power plants in isolation of each other. Only recently have some efforts been initiated to study the Hudson River estuary from a more holistic point of view (Multiplant Impact Study being conducted by Texas Instruments and the Hudson River Study being carried out by Lawler, Matusky, and Skelly), but these studies still have been oriented strongly toward striped bass alone.

Upland Ecosystems

4.83 Natural upland ecosystems are potentially altered or eliminated by construction and operation of power plants in the Hudson River Valley. Operation of cooling towers would result in salt drift, introducing the possibility of vegetation damage occuring in the vicinity of the towers.

Bowline Point Generating Station

4.84 The Orange and Rockland property containing the Bowline generating station is 245 acres. Of this total, Bowline Pond is 53 acres and 192 acres are uplands. Construction of the plant included the filling of about 60 acres of wetlands along Minisceongo Creek. The net effect of plant construction on the site has been to displace all species except those capable of adapting to the mix of urban, suburban, and industrial land use typical of the site and the Haverstraw area. The power plant was connected to an existing transmission corridor by using a 3.4-mile underground transmission line.

4.85 Potential Salt Drift From Cooling Towers. If closed-cycle cooling is required at Bowline Point in the future, the potential exists for damage to vegetation from salt drift produced by cooling towers during the months when river water used for make-up is saline. Although the term "salt drift" is a misnomer, it has been used consistently for decades; the effect of brackish water droplets to plants is due principally to the chloride ion (Boyce, 1954).

4.86 Several factors limit the ability to estimate the potential for damage to vegetation from salt drift from cooling towers at Bowline Point. The acute effect of salt drift from cooling towers on vegetation has only recently become the subject of research. Only two studies reported in scientific journals or other publications have produced reliable data on the response of vegetation to salt

? ?

Reference Indian Point Studies?

drift (McCune et al., 1977; Silberman and McCune, 1978). In these studies, only eleven species of trees and shrubs were tested, only one exposure interval (either 4 or 6 hours) was used for each species, and only seedlings and saplings of nursery stocks were exposed. The response of indigenous and mature plants may be different, and deposition rate response may not be directly proportional to length of exposure. Salt drift impacts to herbs and to flowering and fruiting have not been studied. No data are available for more than 200 species of plants in the Bowline Point area.

Isn't that a large number?

4.87 Rates of salt drift deposition at Bowline Point were estimated for 1964-5, 1974, and 1978 at 0.1 mile intervals to a distance of 2.0 miles from the site of the proposed towers using a computer model (see Appendix E). 1964-5 was selected as representative of a drought year. Hourly meteorological data for 1974 and 1978 (wind speed and direction at 200 or 350 feet, relative humidity, and temperature) and river salinities in conjunction with a cooling tower salinity concentration factor of 2.4 were inputs to the model (McLain, 1979). Since onsite meteorological data are not available for 1964-5, deposition rates for that period were calculated by multiplying 1978 rates by 1964-5:1978 monthly salinity ratios (Table 4-A) (salinity data were available for October-December 1964 and January -September 1965). Isopleths of 1964-5, 1974, and 1978 mean monthly deposition due to the Bowline Point facilities alone are presented in Appendix E.

4.88 Total salt deposition at Bowline Point would also include drift from proposed towers at Indian Point and natural drift mostly from the Hudson River. Maximum, mean monthly, total solute deposition that would result within one mile of Bowline Point from the proposed Indian Point cooling towers (Table 4-15) was estimated using deposition estimates for 1977 (Environmental Systems Corporation, 1978) in conjunction with 1964-5:1978 salinity ratios at Bowline Point. Maximum, mean monthly, natural total solute deposition within one mile of the proposed Bowline Point towers (Table 4-15) was extrapolated from in-situ measurements by Mulchi et al. (1976) and salinity data in Mulchi et al. (1976) and Orange and Rockland Utilities, Inc. (1977).

4.89 Maximum mean monthly total salt drift deposition rates at selected intervals from the site of the proposed towers at Bowline Point are given in Table 4-16 (isopleths in Appendix E do not incorporate the additional salt deposition from natural sources and from towers at Indian Point if they are constructed). Maximum total deposition rates were used to assess potential effects on vegetation.

4.90 Acute No-Visible-Effect Levels for Plants. The Acute No-Visible-Effect Level (ANVEL) of salt deposition for each species tested by McCune et al. (1977) and Silberman and McCune (1978) is presented in Table 4-17. Flowering dogwood, white ash, and Canadian

TABLE 4-15

BOWLINE POINT MEAN MONTHLY 1964-5:1978 SALINITY RATIOS, MAXIMUM POTENTIAL DEPOSITION RATES CAUSED BY PROPOSED INDIAN POINT COOLING TOWERS, AND MAXIMUM NATURAL TOTAL SOLUTE DEPOSITION RATES

MONTH	1964-5: 1978 SALINITY RATIO[a]	MAXIMUM POTENTIAL TOTAL SOLUTES DEPOSITION FROM PROPOSED INDIAN POINT TOWERS[b] (kg/ha/mo)	MAXIMUM AVERAGE NATURAL TOTAL SOLUTES DEPOSITION[c] (kg/ha/mo)
January	53.90	3.935	0.91
February	0.36	0.026	0.91
March	2.20	0.161	0.91
April	1.00	0.073	0.91
May	9.50	0.694	0.91
June	4.82	0.352	0.91
July	1.14	0.083	0.91
August	1.34	0.098	0.91
September	1.16	0.085	0.91
October	3.04	0.222	0.91
November	2.29	0.167	0.91
December	1.47	0.107	0.91

[a] Source: Dr. Howard McClain, Oak Ridge National Laboratory, Personal Communication, December 1979.

[b] Source: Estimated using Environmental Systems Corporation (1978) projection for 1977 and 1964-5:1978 SALINITY RATIOS AT Bowline Poine.

[c] Extrapolated using in-situ measurements by Mulchi et al. (1976) and salinity data in Mulchi et al. (1976) and Orange and Rockland Utilities, Inc. (1977).

TABLE 4-16

MAXIMUM, MEAN MONTHLY, TOTAL SALT DEPOSITION RATES (kg/ha/mo) FOR 1964-5, 1974, AND 1978 AT SELECTED INTERVALS (MILE) FROM THE PROPOSED BOWLINE POINT COOLING TOWERS

	1964-5			1974	1978
MONTH	0.2 mile	0.3 mile	0.9 mile	0.2 mile	0.2 mile
January	47.9	30.4	8.0	6.4	5.5
February	2.2	1.8	1.0	2.0	3.6
March	4.8	3.5	1.3	1.7	1.8
April	1.5	1.3	1.0	1.7	1.5
May	9.1	5.0	2.1	2.1	2.0
June	45.5	20.8	3.5	6.0	9.8
July	46.5	20.8	6.0	1.5	38.8
August	36.6	20.9	6.1	1.5	25.9
September	55.0	28.5	8.2	4.2	44.2
October	82.5	48.8	6.1	9.1	25.9
November	134.8	77.2	10.1	1.9	55.3
December	39.9	27.7	4.3	1.1	8.3

TABLE 4-17

ACUTE NO-VISIBLE-EFFECT LEVELS (ANVEL's) (kg/ha/mo) OF TOTAL SOLUTES DEPOSITED ON NINE DECIDUOUS AND TWO EVERGREEN PLANT SPECIES IN GREENHOUSE AEROSOL EXPOSURE CHAMBERS

SPECIES	kg TOTAL SOLUTES/ HECTARE/MONTH
Tsuga canadensis Canadian Hemlock	10.2[a]
Fraxinus americana White Ash	<91.4[b] (Effective Dose which affected 50% of test organisms (ED50) = 183.0[a])
Cornus florida Flowering Dogwood	91.4[a,b] (ED50 = 254.0[a])
Pinus strobus White Pine	914.4[b]
Forsythia intermedia Forsythia	<1828.8[b]
Quercus prinus Chestnut Oak	1828.8[b]
Robinia pseudo-acacia Black Locust	1828.8[b]
Albizia julibrissin Mimosa	1828.8[b]
Acer rubrum Red Maple	1828.8[b]
Koelreutaria paniculata Golden Rain Tree	5486.4[b]
Hamamelis virginiana Witch Hazel	7315.2[b]

[a] Source: Silberman and McCune, 1978.
[b] Source: McCune et al., 1977.

hemlock are from 20 to 200 times more sensitive than the other species tested. Original values (micrograms $Cl^-/cm^2/4$ or 6 hours) have been converted to kg total solutes/ha/mo for convenience using composition values of Hudson River water at Indian Point (McCune et al. 1977).

4.91 When using ANVEL's and mean monthly deposition rates to assess species effect, it must be assumed that these rates are directly proportional to time and, therefore, directly proportional to each other. The corollary assumption is that the length of exposure is irrelevant to effect. These assumptions have not been confirmed.

4.92 Vegetation in the Vicinity of Bowline Point. Since reliable data are available only for tree and shrub species, herbaceous vegetation was not studied during a two-day reconnaissance of the site. Trees within 0.3 mile of the proposed towers are found mostly on stream and ditch banks, along roadsides, and in parklands. Dominant trees are red maple (Acer rubrum), black locust (Robinia pseudoacacia), tree-of heaven (Ailanthus altissima), weeping willow (Salix babylonica), gray birch (Betula populifolia, and sycamore (Platanus occidentalis). None of the other species listed in Table 4-C were observed. Remaining terrestrial habitats are occupied predominantly by herbaceous old field communities and reed (Phragmites australis) dominated marshes.

4.93 The 0.3-0.9 mile interval is similar to the 0.0-0.3 mile segment with the addition mostly of residential plantings of ornamentals such as flowering dogwood, white pine, forsythia, and mimosa (silk tree). Natural stands of Canadian hemlock do not occur within 0.9 mile of the proposed towers.

4.94 South Mountain-High Tor State Park is located 0.9 mile from the proposed towers. The 700 foot-high mountain is almost completely forested and is generally characterized by mixed deciduous communities. Common canopy species include tulip poplar (Liriodendron tulipifera), black birch (Betula lenta), red maple sugar maple (A. saccharum), red oak (Quercus rubra), black oak (Q. velutina), white ash (Fraxinus americana) and hickories (Carya spp.). Subcanopy dominants include flowering dogwood, witch hazel (Hamamelis virginiana), and striped maple (A. pennsylvanica).

4.95 Potential Acute Impacts to Vegetation at 1974 and 1978 Deposition Rates. None of the species tested would be visibly, acutely affected by 1974 or 1978 maximum, mean monthly, deposition rates as estimated by the computer model (see Appendix E). The highest 1974 rate (9.1 kg/ ha/mo, Table 4-16) would have been 1.1 kg/ha/mo less than the ANVEL of the most sensitive species, Canadian hemlock (Table 4-17). Although the greatest 1978 rate, which would have occurred within 0.2 mile of the proposed tower in November, exceeds the ANVEL of Canadian hemlock and possibly white ash, neither species was observed within a 0.3 mile radius during the site visit. Also white ash would not have leaves in November. The greatest rate in the growing season (44.2 kg/ha/mo) would have been less than one-half of the maximum possible ANVEL for white ash and one-fourth of the rate that injured 50 percent of test organisms.

4.96 Potential Acute Impacts to Vegetation at Drought Year Deposition Rates (1964-5). Of the species tested, only red maple and black locust were observed within 0.3 mile of the proposed tower. Neither would probably be visibly, acutely affected at the estimated 1964-5 deposition rates since ANVEL's for these species are 14.6 times greater than the highest deposition rate that would have occurred at 0.2 mile.

4.97 Canadian hemlock trees growing within 0.3-0.9 mile of the proposed towers could have been visibly affected in 1964-5. Deposition rates during July through December exceeded the ANVEL for Canadian hemlock.

4.98 None of the eleven species tested would be affected by 1964-5 deposition rates beyond 0.9 miles, i.e., within the South Mountain-High Tor State Park forest. Four species are common in the canopy (red maple, white ash) and subcanopy layers (flowering dogwood, witch hazel) of the State Park. However, the total number of species in the South Mountain-High Tor State Park area probably exceeds 200. The effect of salt drift on these species, excluding the four above, is unknown.

4.99 Potential Chronic Salt Drift Impacts to Vegetation. Chronic impacts of salt drift to vegetation are unknown (Talbot 1979). Patterson et al. (1977) have obtained data that suggest that Cl^- and Na^+ may bioaccumulate in leaves of dogwood, black locust, sassafras (Sassafras albidum) and scrub pine (Pinus virginiana). This finding may suggest that threshold levels could be attained or productivity reduced as a result of long-term salt drift exposure. The authors suggest that dogwood may be utilized as a good bioindicator of ion accumulation in plants.

4.100 Potential Salt Drift Impacts to Fauna. The direct physiological effect of salt drift to vertebrates has not been studied but is generally considered to be negligible due to their capacity to regulate body salt (Talbot 1979). Effects to other animals have not been reported. If salt drift alters plant community structure or productivity, fauna would be affected indirectly by loss of food supply or alteration of habitat.

Roseton Generating Station

4.101 The Central Hudson Gas and Electric property containing the Roseton generating station is 133 acres, formerly the site of a brick works. Construction of the Roseton plant included completion of the filling of a small pond that had been the site of fly ash dumping from the adjacent Danskammer plant (F. Dooris, 1977). Because of the character of the previous use of the site, the net effect of plant construction and operation on the existing terrestrial ecosystems is small.

4.102 Potential Salt Drift from Cooling Towers. If closed-cycle cooling is required at the Roseton generating station damage to vegetation from salt drift could result. Potential rates of salt drift deposition at Roseton were estimated for 1964-5, 1974, and 1978 in the same manner as for Bowline Point with the exception of excluding drift from Indian Point since these towers would not contribute to deposition at Roseton. Isopleths of mean monthly deposition due to the proposed Roseton towers are presented in Appendix E. Maximum, mean monthly, total salt drift deposition rates (Roseton tower rates plus natural deposition) at selected intervals from the proposed towers are listed in Table 4-18. These rates were used in conjunction with the acute no-visible-effect levels (ANVEL) to assess potential vegetation effects.

4.103 Vegetation in the Vicinity of Roseton. About 40 percent of the land within 0.3 mile of the proposed towers is forested. Most of the forest occurs on a 240 foot-high east-facing slope. Common canopy trees are red oak, black oak, white oak, striped maple, sugar maple, red maple, tree-of-heaven, butternut hickory, pignut hickory, black birch, white ash, tulip poplar, and beech. Less than ten Canadian hemlocks were observed during the site reconnaissance. Flowering dogwood and witch hazel are common in the subcanopy.

4.104 More than 75 percent of the land between 0.3 and 0.6 mile of the proposed towers is forested. Species composition is similar to the east-facing slope described above with the exception of the northwest-facing slope adjacent to the Cedar Hill Cemetery. This slope possesses dense natural stands of Canadian hemlock; maples, black birch, and beech are also common.

4.105 Less than half of the cemetery is located within 0.6 mile of the proposed towers. Many ornamentals such as dogwood, weeping willow, spruce, pine, and Canadian hemlock are maintained.

4.106 About 16.5 acres of apple orchard occur 0.5-0.6 mile west of the proposed towers. The orchard extends well beyond the 0.6 mile interval.

TABLE 4-18

MAXIMUM, MEAN MONTHLY, TOTAL SALT DEPOSITION RATES (kg/ha/mo) FOR 1964-5, 1974, AND 1978 AT SELECTED INTERVALS (MILE) FROM THE PROPOSED ROSETON COOLING TOWERS

	1965			1974	1978	
MONTH	0.2 mile	0.3 mile	0.4 mile	0.2 mile	0.2 mile	0.3 mile
January	3.9	2.9	2.2	1.8	1.8	1.5
February	2.3	1.7	1.3	1.9	2.3	1.7
March	1.9	1.5	1.2	1.6	1.9	1.5
April	1.5	1.2	1.1	1.6	1.5	1.2
May	1.6	1.2	1.1	1.5	1.6	1.2
June	9.6	10.2	5.8	1.8	2.0	1.4
July	29.3	13.4	7.5	1.8	14.6	6.9
August	19.7	9.1	5.4	1.8	4.0	2.3
September	11.0	5.4	3.4	1.8	3.0	1.9
October	27.4	15.8	9.5	2.0	1.8	1.4
November	23.4	14.3	8.9	1.8	1.8	1.4
December	3.1	2.3	1.7	1.8	1.8	1.4

4.107 Potential Acute Impacts to Vegetation at 1974 and 1978 Deposition Rates. Five of the eleven species tested for salt drift effects (red maple, white ash, Canadian hemlock, dogwood and witch hazel) occur within 0.2 miles of the proposed towers but would not have been acutely, visibly affected in 1974 or 1978 (Tables 4-17 and 4-18).

4.108 Potential Acute Impacts to Vegetation at Drought Year Deposition Rates (1964-5). The ANVEL of Canadian hemlock would have been exceeded only to a distance of less than 0.4 mile in 1964-5 (Table 4-17 and 4-18). Fewer than 10 solitary hemlocks were observed less than 0.4 mile of the proposed towers during the site reconnaissance. The natural stands of hemlock adjacent to the cemetery would not have been affected since they are 0.4 mile from the proposed towers. Red maple, white ash, dogwood, and witch hazel would not have been visibly, acutely affected at any interval. ANVEL's for the remaining 200 or more indigenous species are not known. The potential impact of salt drift to the orchard is not known since apple trees have not been tested for the effects of salt drift. Similarly, the possible salt drift effect to almost all ornamental species in the cemetery cannot be projected.

4.109 Potential Chronic Salt Drift Impacts to Vegetation and Fauna. As described in previously, chronic effects of salt drift to vegetation are unknown. Direct effects on vertebrates are unlikely due to their osmoregulatory capacity. Direct impacts on other animals are not known. Indirect effects due to changes in habitat are possible.

Cumulative Impact of All Generating Stations

which plants included

4.110 Presently existing power plants along the Hudson River occupy about 1500 acres of land. Proposed facilities would probably require about an additional 1500 acres. The impact of these facilities on upland ecosystems will vary from site to site depending on previous use and condition of the land. In general, the changes that would occur are most likely to be similar to those described above for Bowline and Roseton. The overall land area devoted to power plants would be a small percentage of the total land area of the Hudson River Valley.

Wetland Ecosystems

4.111 Construction of power plants along the shores of the Hudson River estuary could potentially affect wetland ecosystems by filling for use in the construction of necessary facilities and by modification of upland runoff patterns.

comprehensive
record of EPA case
- Point out pieces
[illegible] other
get the case
+ possible
outcomes

Bowline Point Generating Station

4.112 Construction of the Bowline Point Generating Station resulted in the loss to filling of about 60 acres of wetlands along Minisceongo Creek. The creek channel was also relocated to empty directly into the Hudson River at a point adjacent to the fuel storage area, diverting it from the Gassy Point Marsh to the North (see Figure 1-3). The wetland community covered with fill has been completely lost. The effect of the creek diversion on Grassy Point Marsh is unknown, but some moderate alteration is likely to have occurred because of the changed water relationships.

Roseton Generating Station

4.113 Construction of the Roseton station did not alter wetlands in the area (F.Dooris, 1977).

Cumulative Impact of All Generating Stations

4.115 The area of wetlands involved in construction of the older 59th Street, Lovett, Danskammer, and Albany stations is unknown. Wetlands eliminated at Bowline and Roseton totalled about 60 acres. No wetlands were involved at Indian Point. Required compliance with New York State wetland protection legislation, Section 404 of the Federal Water Pollution Control Act Amendments of 1972, and Section 10 of the River and Harbor Act of 1899 should minimize effects of future power facilities on wetlands along the Hudson River.

Aquatic Ecosystems

4.115 The aquatic ecosystem of the Hudson River estuary can be affected by power plant operation through discharges of heated water and by entrainment and impingement of organisms. Chemical contaminants discharged from the power plants are not expected to have detrimental effects on aquatic ecosystems. Extensive field measurements have been made by the utilities to determine the effects of presently operating stations and to provide a baseline for predicting the impacts of future power plants to be operated on the river. Much of this effort has focused on the striped bass because of its recreational and commercial importance in the region. Simulation models have been developed to help predict the long term effect on this population.

Impacts of Bowline Point Generating Station

1979-1980

4.116 Data are available for the years 1971 through 1977 for assessing the impact of the Bowline Units 1 and 2 on the aquatic ecosystem of the Hudson estuary in the vicinity of Bowline Point.

why not Con Ed's reports for multiplant?

The data include the effects of the operation of Unit 1 since 1972 and Unit 2 since 1974. The following discussion draws on data given in Lawler, Matusky, and Skelly (1974, 1975a, 1976a, 1978), Ecological Analysts (1976a), and Orange and Rockland (1977).

4.117 Phytoplankton. The applicant has assessed entrainment and thermal discharge effects on phytoplankton by comparing abundance, species composition, and the rate of primary production in the intake area of Bowline Pond and in the discharge area in the adjacent river (Lawler, Matusky, and Skelly, 1975b, 1976a, 1978; Orange and Rockland, 1977). No significant differences were found in mean abundance between the intake vicinity and the discharge areas. Diatom abundance significantly was different, but abundance patterns were different from year to year (diatoms more abundant at discharge than intake in 1973 and 1975 with the reverse being found in 1974), suggesting that these differences may have been due more to different evironmental conditions in the river and Bowline Pond than to the effects of entrainment. Considerable seasonal variation has been observed in phytoplankton abundance, but no long term trend has been found to correlate with plant operation in the Bowline area.

4.118 No gross effects on primary productivity were found based on intake-discharge comparisons (Orange and Rockland, 1977). Reductions in primary productivity appeared to range from 10 to 20 percent but these apparent differences may have resulted from intake sampling techniques.

4.119 Presently available data do not indicate any significant impact of the power plant on phytoplankton in the Bowline vicinity. The absence of any long term trends over the years in phytoplankton abundance suggests a lack of plant-induced changes in the Bowline Point vicinity. Short generation times of phytoplankton and rapid recycling of nutrients contained in any algal cells killed by entrainment may tend to minimize any effects.

4.120 Zooplankton. Studies on the distribution and abundance of microzooplankton during the years 1972-1977 have shown no spatial or temporal distribution patterns which suggest significant effects of power plant entrainment at the population or community levels (Orange and Rockland, 1977; Lawler, Matusky and Skelly 1978). Entrainment survival studies showed that microzooplankton generally sustained entrainment mortalities averaging 4 to 17 percent in 1975 and 1976 (See Table 4-19 for sample data). Microzooplankton entrainment mortality was independent of temperatures below 37 C, the highest temperature examined. Laboratory investigations of thermal tolerance in major microzooplankton species indicates that substantial entrainment mortality should occur only under full-load and/or reduced pump-flow conditions, except for the most thermally sensitive species.

TABLE 4-19

ENTRAINMENT MORTALITY OF ZOOPLANKTON (PERCENT) AT BOWLINE GENERATING STATION. NUMBERS ARE DIFFERENCES IN INITIAL SURVIVAL BETWEEN INTAKE AND DISCHARGE SAMPLES.

SPECIES	July 29 - August 5, 1975 Temp. 28C ΔT 8C	September 29 - October 1, 1975 Temp. 20C ΔT 7C	December 16 - December 17, 1975 Temp. 6C ΔT 6C	SUMMARY FOR 1975
TOTAL MICROZOOPLANKTON	21	--	21	12
Keratella cochlearis	--	--	--	--
Coperod mauplii	19	--	29	--
Eurytemora affinis	25	--	39	--
Acartia tonsa	--	*	--	--
Halicyclops fosteri	12	--	--	--
Bosmina longirostus	27	--	39	22
TOTAL MACROZOOPLANKTON	--	15	--	--
Monoculodes edwardsi	--	--	--	--
Gammarus daiberi	--	--	--	--
Edotea triloba	--	--	--	--
Neomysis americana	--	--	--	--
Chaoborus punctipennis	--	--	--	--

*No organisms of this species collected.
-No significant difference found between intake and discharge survival.

Source: Ecological Analysts, 1976a.

4.121 Studies of the distribution and abundance of macrozooplankton conducted from 1972 to 1977 have demonstrated no significant effects of power plant entrainment at the population or community level (Orange and Rockland, 1977; Lawler, Matusky, and Skelly, 1978). Entrainment survival studies showed that macrozooplankton tend to be less susceptable to entrainment mortality than microzooplankton, and averaged less than 5 percent mortality (see Table 4-19 for sample data). However, the mysid Neomysis americana sustained substantial mortality at discharge temperatures in excess of 32 C. Latent mortalities of macrozooplankton were insignificant at discharge temperatures below about 25 C, but increased with discharge temperatures from 25 to 35 C. Thermal tolerance laboratory investigations predicted that effects of thermal stress would be negligible under most conditions for most species entrained. However, Neomysis americana is predicted to sustain substantial or total mortality under most daytime operational modes during the summer months. During reduced-load nighttime operation (when involvement is maximum) no entrainment mortality is expected.

4.122 Benthic Animals. Benthic communities normally exhibit considerable temporal and spatial variation in abundance and species composition. Studies of benthic communities in the Bowline Point area from 1972 to 1976 indicated no significant effects on the benthos that could be directly attributed to power plant generation. No effects on the benthic community in the Bowline vicinity attributable to the thermal plume are evident from the available data. Observed differences among sample stations were more likely to be due to other environmental and physical factors, such as salinity changes, season of the year, and depth. Plume surveys and bottom temperatures taken when benthic samples were gathered indicate that the thermal discharge rises to the river surface. Where bottom communities in the discharge vicinity experience any temperature increase at all, it is apparently only 1 to 3 F. Such a small temperature difference is unlikely to affect benthic animals directly to any significant extent.

4.123 Other factors that may affect the benthic community include scouring of the bottom near the intakes and the discharge ports and loss of planktonic larvae by entrainment mortality. Planktonie larvae of the dipteran Chaoborus punctipennis are the only benthic organisms for which entrainment data are available. No entrainment mortality was statistically discernible. Other species are not likely to be seriously affected.

4.124 Entrainment of Fish Eggs, Larvae, and Juveniles. The abundance of fish eggs and larvae is generally greater in the Hudson River proper than in Bowline Pond, where the cooling water intake for the Bowline Point Plant is located. Entrainment sampling has been carried out using collecting devices at the plant intake and discharge to estimate the types and numbers of organisms carried through the plant. Fish eggs, larvae, and juveniles small enough to pass through the traveling intake screen (0.95 cm or 3/8 inch) are entrained with the cooling water passing through the condenser and then are discharged back into the Hudson River (see Figures 1-2, 1-7, and 1-8). The primary factors that may cause adverse effects to entrained organisms are mechanical and thermal shock. The quantity of organisms entrained changes with seasonal variation in the abundances of fish eggs and larvae occurring in surrounding waters.

4.125 In addition to the quantity of organisms entrained, the rates of immediate and latent entrainment mortality must be considered in assessing the significance of entrainment. Sublethal effects of passage through the power plant may also be important but are not well known. The immediate effects of entrainment are assessed through the observation of organisms collected from the plant discharge. Because plant conditions vary depending on operational load, season, and equipment used, entrainment mortality varies through time. To assess the long range effects of power plant entrainment, the loss due to entrainment must be compared to species standing stocks.

4.126 It is difficult to measure accurately the numbers of eggs, larvae, and juveniles entrained by a power plant. When nets are used to sample entrained organisms, the major sampling problems include net avoidance, clogging of nets, extrusion of eggs and larvae, and inaccurate measurement of the water volume sampled. Sampling with a pump and larval table alleviates some of the problems associated with net sampling but pumps may damage larger juveniles and fragile yolk-sac larvae. Ecological Analysts (1976, 1977) have documented the sampling differences that occur between the pump-larval table method and net systems. At the Bowline Point Plant, entrainment rates have generally been estimated using net samplers, while entrainment survival was studied using the pump-larval table method. In an assessment of ichthyoplankton sampling programs used at Hudson River power plants, Carpenter (undated), an Environmental Protection Agency consultant, concluded that the Bowline sampling methods would tend to underestimate entrainment of fish eggs, larvae, and juveniles. The magnitude of the bias was not estimated, however.

4.127 The following discussion is based largely on studies conducted during 1977. These results are generally also representative of data collected during 1973-1976 (Orange and Rockland, 1977). Larvae of the bay anchovy were dominant among entrained fish at the Bowline Point Power Plant in 1977, accounting for nearly 70 percent of the total (see Table 4-20). Atlantic tomcod, striped bass, and

TABLE 4-20

ICHTHYOPLANKTON COLLECTED DURING ABUNDANCE SAMPLING AT THE BOWLINE POINT PLANT DISCHARGE DURING 1977

SPECIES	LIFE STAGE	NUMBER COLLECTED	PERCENT COMPOSITION
Bay anchovy	Larvae	13,375	69.8
Atlantic tomcod	Yolk-sac larvae	2,366	12.3
Striped bass[a]	Larvae	763	4.0
Unidentified[a]	Larvae	485	2.5
White perch	Egg	405	2.1
Bay anchovy	Juvenile	258	1.3
Clupeids	Larvae	248	1.3
White perch	Larvae	227	1.2
Morone spp.	Larvae	214	1.1
Silversides	Larvae	145	0.8
Striped bass	Juvenile	135	0.7
Hogchoker	Larvae	108	0.6
Atlantic tomcod	Larvae	70	0.4
Clupeids	Egg	69	0.4
American eel	Junenile	52	0.3
Striped bass	Yolk-sac larvae	33	0.2
Bay anchovy	Egg	30	0.2
Rainbow smelt	Larvae	22	0.1
Sunfish	Larvae	20	0.1
White perch	Juvenile	19	0.1
Northern pipefish	Juvenile	16	0.1
Atlantic silverside	Larvae	14	0.1
Atlantic tomcod	Juvenile	10	0.1
Unidentified[a]	Egg	9	0.0
Rainbow smelt	Juvenile	8	0.0
Clupeids	Juvenile	7	0.0
White perch	Yolk-sac larvae	7	0.0
Tessellated darter	Yolk-sac larvae	7	0.0
Minnows	Larvae	6	0.0
American shad	Larvae	4	0.0
Hogchoker	Juvenile	4	0.0
Unidentified[a]	Juvenile	4	0.0
Killifish	Larvae	4	0.0
Killifish	Juvenile	3	0.0
Clupeids	Yolk-sac larvae	3	0.0
Hogchoker	Yolk-sac larvae	3	0.0
Weakfish	Juvenile	2	0.0
Silversides	Juvenile	1	0.0
Striped bass	Egg	1	0.0
Winter flounder	Larvae	1	0.0
Yellow perch	Yolk-sac larvae	1	0.0
Unidentified	Egg	1	0.0
Atlantic tomcod	Egg	1	0.0
Walleye	Larvae	1	0.0
Weakfish	Larvae	1	0.0
Cyprinids	Yolk-sac larvae	1	0.0
Unidentified	Yolk-sac larvae	1	0.0

[a] Indicates that organisms were damaged; 54 percent of the damaged larvae occurred during the period of peak bay anchovy abundance (after 6 July). Abundance of species other than bay anchovy in samples collected during this period was very low. Other damaged organisms were collected throughout the sampling period when striped bass, white perch, clupeids, and bay anchovy were abundant.

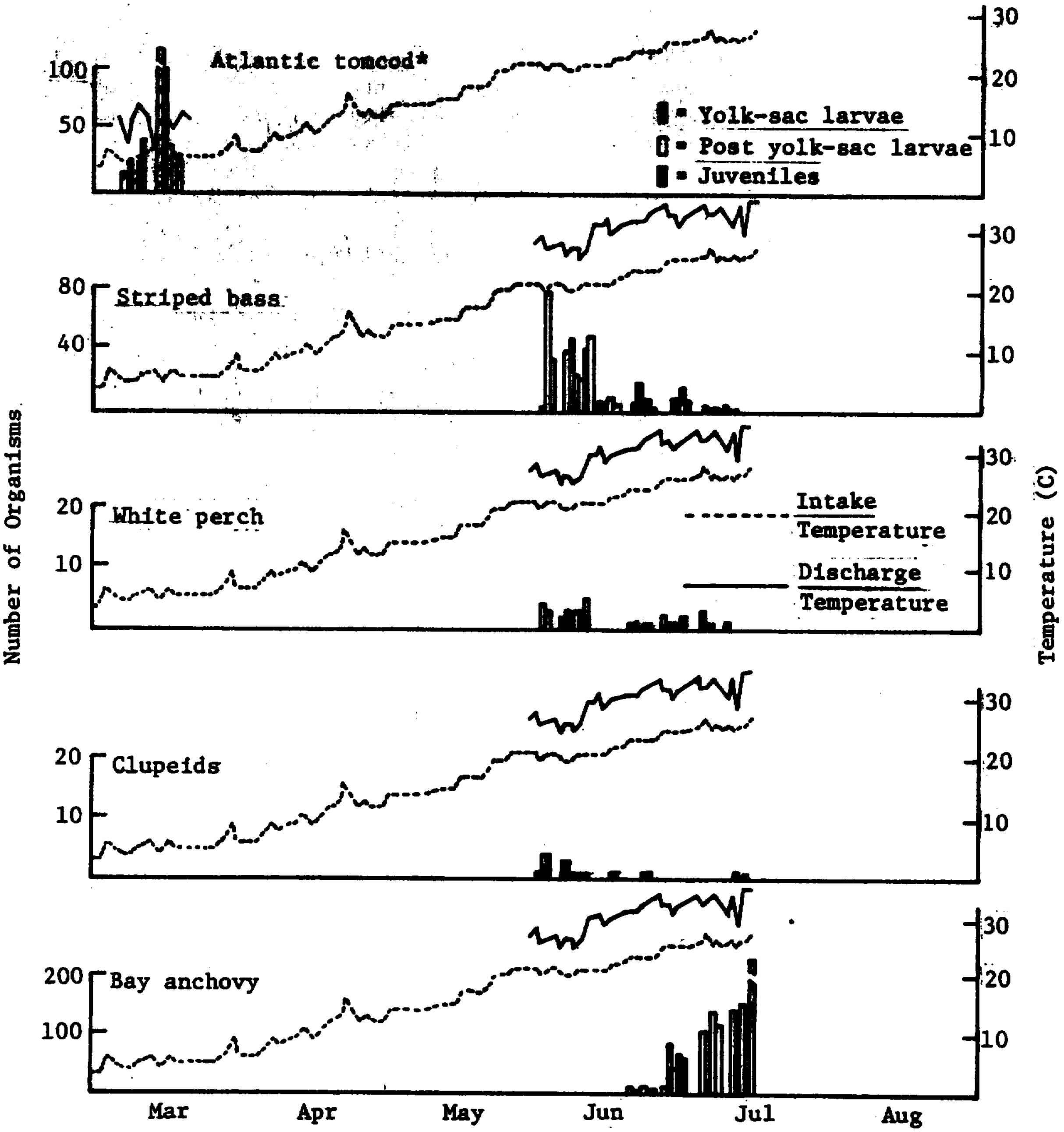
Source: Ecological Analyst, 1978a.

white perch were also entrained in relatively large numbers, in total accounting for another 18% of entrained fish. As a result of the time of spawning for these species, the tomcod was primarily entrained during the month of March, while striped bass, white perch, and bay anchovies were entrained during June and July (see Figure 4-3).

4.128 Entrainment mortality at the Bowline Power Plant has been estimated through comparison of survival rates in fish collected at the plant intake and discharge. Intake survival has been used as a control because organisms collected at the intake had not been entrained but had been subjected to sampling and handling stress. The entrainment survival percentages (proportion surviving at intake divided by proportion surviving at discharge times 100) for dominant entrained fish species in 1977 are presented in Table 4-21. Although the following discussion is based largely on 1977 data, studies carried out in 1975-1976 show the same general results (Orange and Rockland, 1977).

4.129 Initial entrainment survival for striped bass, white perch, and clupeids is generally greater than 50 percent for discharge temperatures below 30 C. At higher temperatures, entrainment survival is generally low. The yolk-sac larvae of the Atlantic tomcod consistently showed high initial survival (84 to 85 percent). Entrainment survival in the bay anchovy is difficult to assess because this species is apparently sensitive to handling and shows very high mortality even in intake samples (Orange and Rockland, 1977). In most species studied, entrainment mortality appears to be related primarily to thermal stress (Ecological Analysts, 1978b) and, there fore, is dependent on the operational conditions of the plant. Latent entrainment survival measured after 96 hours is less than initial survival, but this is difficult to assess because substantial mortality occurs in control (intake) as well as discharge samples that are held to estimate latent mortality.

4.130 Utilities and their consultants have calculated estimates of entrainment-related loss of fish eggs, juveniles, and larvae based on species standing crops, rates of entrainment, and survival ratios. These estimates are expressed as the number of larvae killed by entrainment in a given year divided by the standing crop of the larvae between River Mile 30 and River Mile 50. Losses for the following species have been estimated:



*Tomcod spawned in February would not appear in March samples.

FIGURE 4-3
SEASONAL DISTRIBUTION OF ICHTHYOPLANKTON COLLECTED
AT THE BOWLINE POINT PLANT DURING 1977

TABLE 4-21

ENTRAINMENT SURVIVAL OF ICHTHYOPLANKTON AT THE BOWLINE POINT PLANT DURING 1977

SPECIES	YOLK-SAC LARVAE		POST-YOLK SAC LARVAE		JUVENILES	
	TEMPERATURE (C)	PERCENT SURVIVAL	TEMPERATURE (C)	PERCENT SURVIVAL	TEMPERATURE (C)	PERCENT SURVIVAL
Striped bass	20.0-29.9	--	20.0-29.9	97 (NS)	20.0-29.9	90 (NS)
	30.0-32.9	--	30.0-32.9	100 (NS)	30.0-32.9	90 (NS)
	33.0-35.9	--	33.0-35.9	41	33.0-35.9	43
White perch	20.0-29.9	--	20.0-29.9	62	20.0-29.9	--
	30.0-32.9	--	30.0-32.9	16	30.0-32.9	--
	33.0-35.9	--	33.0-35.9	48	33.0-35.9	--
Clupeids	20.0-29.9	--	20.0-29.9	51 (NS)	20.0-29.9	--
	30.0-32.9	--	30.0-32.9	--	30.0-32.9	--
	33.0-35.9	--	33.0-35.9	--	33.0-35.9	--
Bay anchovy	20.0-29.9	NE	20.0-29.9	NE	20.0-29.9	--
	30.0-32.9	NE	30.0-32.9	NE	30.0-32.9	--
	33.0-35.9	NE	33.0-35.9	NE	33.0-35.9	--
Atlantic tomcod	5.5-13.9	84	5.5-13.9	--	5.5-13.9	--
	14.0-17.9	85 (NS)	14.0-17.9	--	14.0-17.9	--

Note: Dashes indicate less than five organisms collected at the intake or discharge.
(NE) indicates that no estimate of entrainment survival was made.
(NS) indicates survival at the discharge not significantly lower than that at the intake for a one-tailed z-test at the $\alpha = 0.05$ level.

SPECIES	PERCENT LOSS TO STANDING CROP FROM ENTRAINMENT[a] 1974	1975	SOURCE
White Perch	0.37	1.61	Orange and Rockland (1977)
Striped Bass	2.55	2.95	McFadden (1977)
Alosa spp. (herring)	0.03	0.09	Orange and Rockland (1977)

[a] Standing crop between River Mile 30 and River Mile 50.

Quantitative estimates have not been made for other species affected such as the bay anchovy and Atlantic tomcod.

4.131 Fish Impingement. The Bowline Point Station intake structure is divided into six bays, three for each of the two generating units (see Chapter 1). A traveling screen and screenwash pump system is used in each bay for cleaning the screen with a spray of water. The traveling screens are constructed of 0.95 cm (3/8 inch) mesh to prevent larger fish or debris from passing through the plant with the cooling water. Materials retained on the screen are removed by the spray of water and discharged on the northeast side of the intake. When impingement sampling is carried out, fish retained on the screen are sorted from the debris and collected for study. A sampling program for impinged fish was initiated in December 1972 and has continued at a minimum of once a month to the present. Since 1974, impingement sampling has been performed at least once per week, and data are now available for samples taken through December 1977.

4.132 A total of about 60 fish species have been impinged at Bowline Point. Based on the five years of data presented in Table 4-22, impingement was dominated by white perch (60.5 percent average), with striped bass (8.4 percent average), blueback herring (7.0 percent average), rainbow smelt (6.0 percent average) alewife (5.4 percent average), and Atlantic tomcod (3.5 percent average) also impinged in substantial numbers. Weakfish, bluefish, and bay anchovy may also be impinged in years when salt intrusion causes river conditions in the vicinity of the plant to favor these marine species.

4.133 Estimates of total numbers of fish impinged for selected species are presented in Table 4-23. As shown in the table, impingement varies considerably from year to year. Because of the seasonal nature of impingement for most species (see Figures 4-4 and 4-5), the annual impingement total is sensitive to the relative magnitudes of flow rate and impingement rate at any point in time. Prior to 1974, only one unit was in operation at Bowline Point, therefore impingement was lower in 1973. No long term trends in numbers of fish impinged are evident.

TABLE 4-22

RELATIVE RANKING OF FISH SPECIES BY NUMBERS IMPINGED AT BOWLINE POINT GENERATING STATION FOR 1973 THROUGH 1976

	1973[a]		1974		1975		1976		1977	
RANK	SPECIES	PERCENT OF TOTAL[b]	SPECIES	PERCENT OF TOTAL[b]	SPECIES	PERCENT OF TOTAL[b]	SPECIES	PERCENT OF TOTAL[b]	SPECIES	PERCENT OF TOTAL[b]
1	White Perch	45.9	White perch	57.2	White perch	64.6	White perch	84.7	White perch	50.3
2	Alewife	13.3	Striped bass	13.2	Rainbow smelt	13.9	Striped bass	6.7	Rainbow smelt	10.8
3	Blueback herring	10.8	Blueback herring	10.1	Striped bass	11.5	Rainbow smelt	3.6	Blueback herring	10.0
4	Atlantic tomcod	7.5	Alewife	5.9	Blueback herring	3.0	Blueback herring	0.9	Gizzard shad	7.3
5	Weakfish	7.2	Atlantic tomcod	3.8	Atlantic tomcod	1.7	Gizzard shad	0.7	Striped bass	6.4
6	Striped bass	4.4	Hogchoker	2.6	Alewife	1.2	Atlantic tomcod	0.5	Alewife	6.0
7	Bay anchovy	2.7	Rainbow smelt	1.9	Gizzard shad	1.0	Alewife	0.5	Atlantic tomcod	4.2
8	Hogchoker	2.1	American shad	1.2	Bluefish	0.8	Tessellated darter	0.4	Hogchoker	1.2
9	Bluefish	1.9	Bluefish	1.0	Hogchoker	0.5	Hogchoker	0.4	Bay anchovy	1.0
10	White catfish	0.7	Bay anchovy	1.0	Bay anchovy	0.4	Bay anchovy	0.3	White catfish	0.5
Ten Most Abundant Species (percent of total)		96.5		97.1		98.5		98.7		97.7

[a] Only one unit operating

[b] Percent by numbers

Source: Orange and Rockland, 1977; Lawler, Matusky, and Skelley, 1978.

Table 4-23

ESTIMATES OF TOTAL IMPINGEMENT AT BOWLINE POINT FOR SELECTED SPECIES OF FISH DURING 1977

	TOTAL FISH IMPINGED					
SPECIES	1973[a]	1974	1975	1976	1977	AVERAGE
White Perch	99,659	356,939	391,147	275,670	149,628	254,609±
Striped Bass	8,837	82,205	82,059	25,670	19,072	43,568±
Atlantic Tomcod	12,584	15,612	16,179	4,561	12,778	12,343±
Alewife	19,975	22,323	8,468	5,550	Data Not Available	14,079±
Blueback Herring	18,797	44,969	25,564	5,460	Data Not Available	23,698±
TOTAL	159,852	522,048	523,417	316,911	Data Not Available	380,557

[a] Only unit one operating.

SOURCE: Orange and Rockland, 1977; Lawler, Matusky & Skelly, 1978.

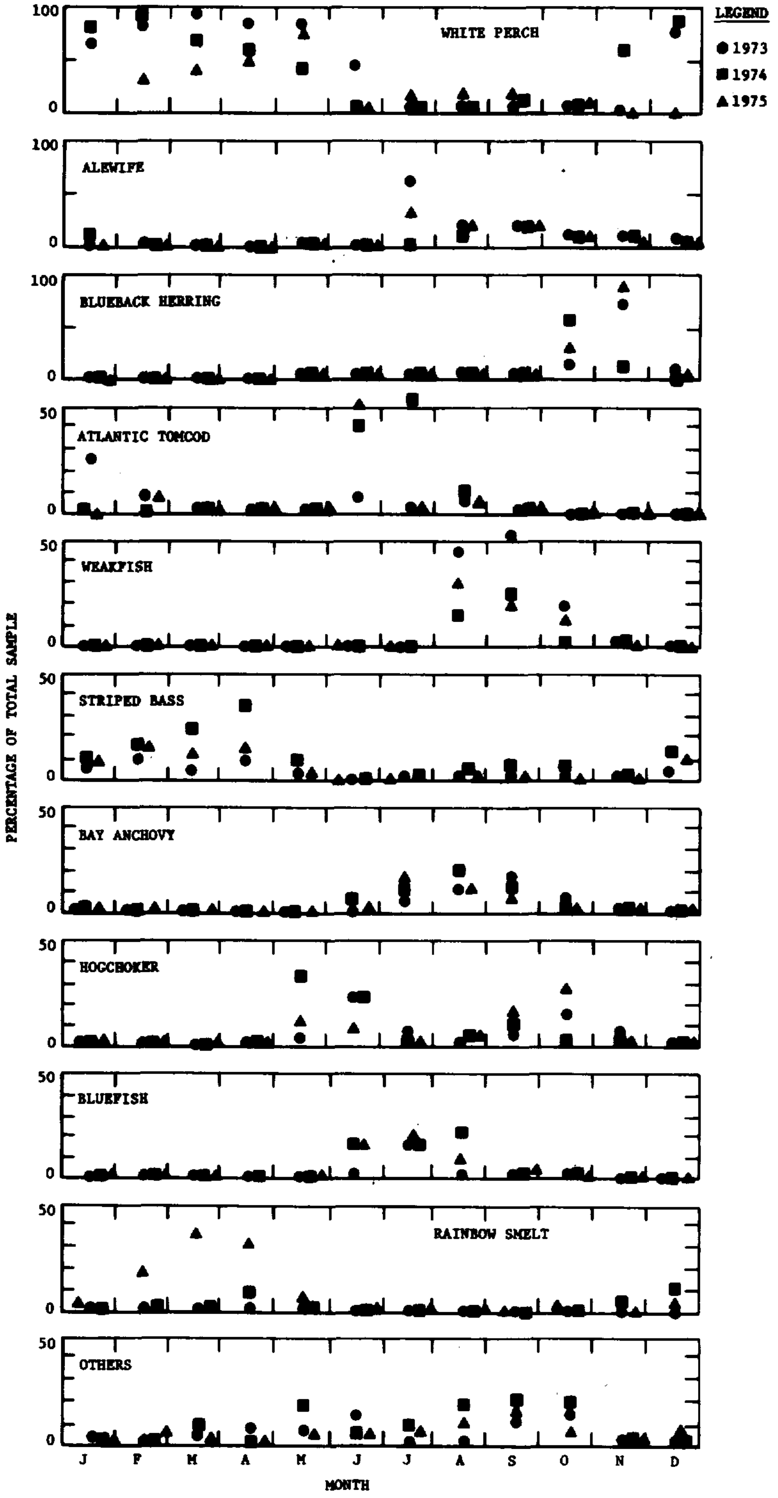
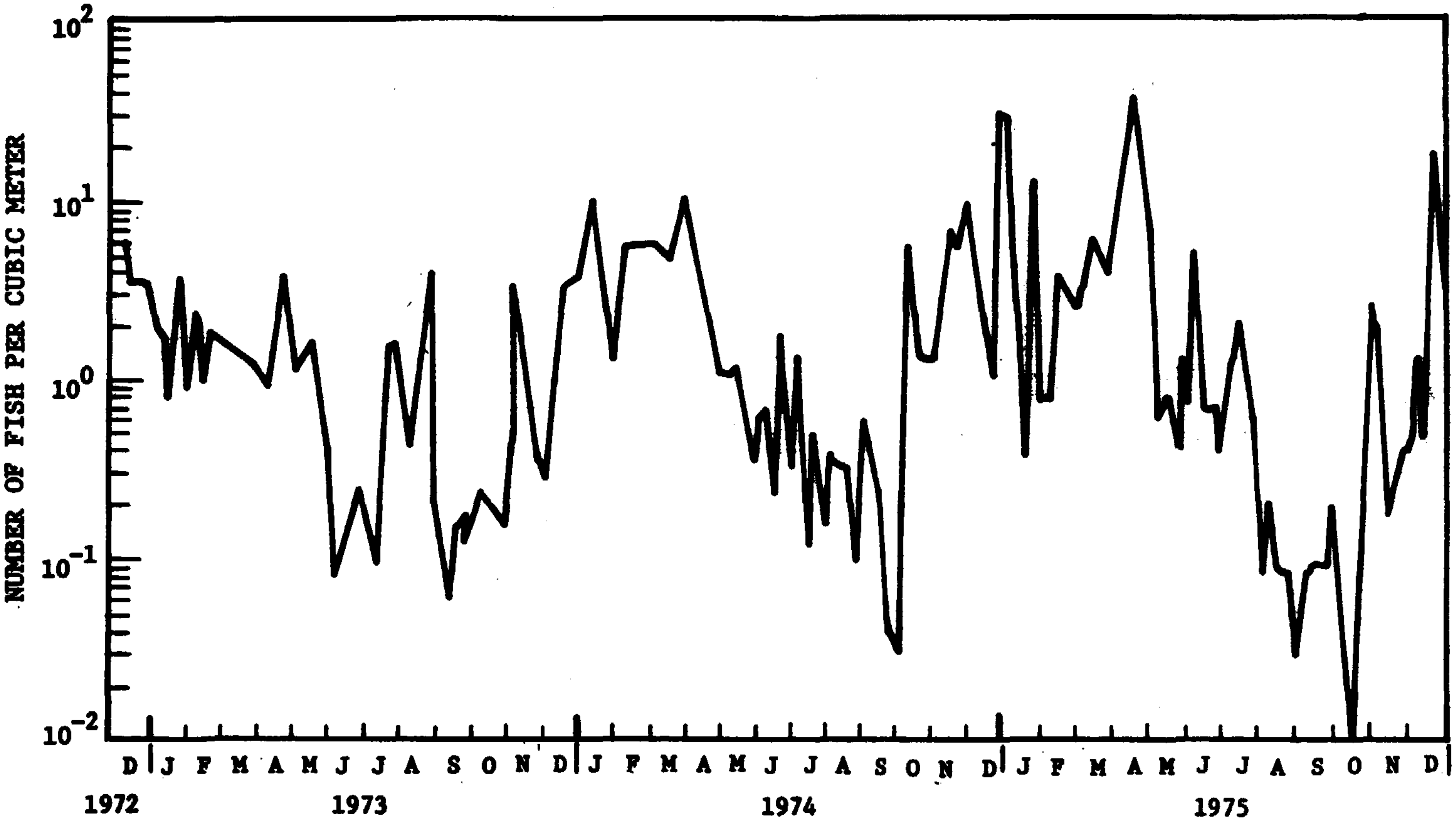


FIGURE 4-4
SEASONAL OCCURRENCE OF VARIOUS SPECIES
IN IMPINGEMENT SAMPLES AT THE BOWLINE GENERATING STATION



Source: Orange and Rockland, 1976.

FIGURE 4-5
SEASONAL VARIATION IN RATE OF FISH IMPINGEMENT
AT THE BOWLINE POINT POWER STATION

4.134 In general, young of the year and yearlings tend to dominate impinged assemblages. Many species show increased impingement rates at night. Impinged fish do not seem to represent the less fit or weaker individuals in a population (Orange and Rockland, 1977). After impingement on the traveling screen and discharge near the intake, the probability for re-impingement of an individual fish has been estimated at 15 to 65 percent, reduced to 10 percent after 24 hours (Orange and Rockland, 1977).

4.135 Impingement survival studies were conducted at the Bowline Point Generating Station in 1974 through 1977 (Orange and Rockland, 1977). Initial and latent (48 to 156 hours) survival were examined to determine the overall effects of the impingement process on affected individuals. Impingement survival at Bowline Point varies with the species of fish and the screenwashing frequency. For example, high initial survival of striped bass (95 percent), white perch (84-97 percent), and Atlantic tomcod (100 percent) was observed during 1976-1977 under continuous screenwash conditions (see Table 4-24). Survival for intermittent screenwash was lower than that for continuous screenwash, and survival of clupeids was lower than that of other species (66 percent for continuous screenwashing; 25 percent for intermittent screenwashing). None of the test clupeids survived the latent holding period. It has been difficult to assess latent impingement mortality because high latent mortality was observed in control organisms (Orange and Rockland, 1977).

4.136 The impact of fish impingement at the Bowline Point Plant can be partially assessed by comparing the number of fish lost through impingement to the number of fish in the source population. The fraction lost through impingement can be calculated by dividing the number impinged by the population standing crop between River Mile 30 and River Mile 50. To provide a conservative estimate of impingement effects, 100 percent mortality among impinged fish has been assumed. Several sampling problems are involved, and a number of assumptions must be made in estimating total numbers of fish impinged and the population standing crop. The procedures that have been followed are summarized by Orange and Rockland (1977) and evaluated in Barnthouse and Van Winkle (1979) and Van Winkle and Barnthouse (1979). Under the assumptions used by Orange and Rockland, the population loss due to impingement of four selected species ranged from 0.001 percent (bay anchovy) to 1.2 percent (white perch) in 1975 and 1976 (see Table 4-25).

4.137 Several factors have been identified that influence impingement estimates at the Bowline Point Plant (Barnthouse, 1979). One of these is the use of flow rates in the extrapolation of weekly or twice-weekly samples to estimates of total impingement. This

TABLE 4-26

IMPINGEMENT SURVIVAL AT BOWLINE POINT FOR SELECTED FISH SPECIES DURING 1976-1977

DATE	SPECIES	NUMBER OF FISH	PERCENT SURVIVAL	
		(1976)	INITIAL	96-HOUR
Jan-Apr(a)	White perch	314	91	23
	Striped bass	45	93	11
Nov-Dec	White perch[a]	5,870	97	55
	White perch[b]	2,620	88	25
	White perch[c]	302	100	23
	White perch[d]	664	92	19
	White perch[e]	1,575	94	9
	White perch[f]	134	--	14
	Atlantic tomcod[a,b]	58	100	100
	Striped bass[a]	418	95	58
	Striped bass[b]	269	92	21
	Striped bass[c]	35	100	20
	Striped bass[d]	32	100	34
	Striped bass[e]	172	96	13
	Clupeid[a]	137	66	0
	Clupeid[b]	50	25	0
		(1977)		
Jan-Feb	White perch[a]	1,946	84	26
	White perch[d]	173	99	25
	White perch[b]	53	74	14

[a] Collection pit samples under continuous screenwash mode.
[b] Collection pit samples under intermittent screenwash mode.
[c] Control samples from impingement collection pit.
[d] Discharge pipe samples under continuous screenwash mode
[e] Discharge pipe samples under intermittent screenwash mode
[f] Cpntrol samples from impingement sluiceway discharge pipe.

Source: Orange and Rockland, 1977.

TABLE 4-25

MONTHS OF GREATEST AND LEAST IMPINGEMENT OF STRIPED BASS AT POWER PLANTS ON THE HUDSON RIVER

	MONTHS OF GREATEST IMPINGEMENT			MONTHS OF LEAST IMPINGEMENT		
POWER PLANT	1973	1974	1975	1973	1974	1975
Bowline Point	1,2,4,12	1-3	1,3,4,12	6,8,-10	6-9	6,8-11
Lovett	4,8,11,12	1,2,4	1-4	1,5,7,10	5,7-9	5,7,8,10
Indian Point 1		1,3,4,12			6-9	
Indian Point 2	1,3,4,12	1-3,5	2-4,7,8	5,7,9,10	6,7,9,10	3,5,6,11
Roseton		5,6,10,11			1-4	
Danskammer 1 and 2	9-12	6-9		1-4	1-3,5	
Danskammer 3 and 4	9-12	6-9		1,3-5	2-4,11	
Albany		6-9			1-3,12	

Source: Barnthouse et al., 1977.

procedure is based on the assumption that impingement is directly proportional to the volume of water entering the plant. Although this assumption may not be totally valid, it is not expected to introduce a systematic error or bias into the results. However, Barnthouse (1979) has identified the following four biases which may potentially affect impingement estimates:

- Collection Efficiency -- Not all impinged fish are actually collected and counted during screenwash monitoring. This causes impingement estimates to be lower than the number of fish actually impinged.

- Reimpingement -- Depending on the relative location of impinged fish return and water intakes, fish may be impinged more than once. This bias would tend to overestimate the occurrence of impingement.

- Impingement on Inoperative Screens -- When a screen is inoperative and cannot be rotated and washed, it continues to impinge fish. A screen that is inoperative for one to five days may impinge about 11 percent as many fish as would a normally operating screen during that period. Such breakdowns occurred "on many occassions from 1974 through 1976" at Bowline (Barnthouse, 1979) and would cause an underestimate of impingement.

- Impingement Survival -- Not all impinged fish are killed. For some species (notably Atlantic tomcod), a substantial proportion of impinged fish appear to survive. The assumption that all impinged fish are killed would tend to inflate estimates of impingement impact.

In an assessment of these biases at the Bowline Point Plant, Barnthouse (1979) concluded that no adjustment factors in excess of 20 percent would be required for existing impingement estimates for clupeids and Morone spp. (Orange and Rockland, 1977), but in the case of Atlantic tomcod the utility consultant appears to have overestimated the impact of impingement during the September to April period by a factor of 1.7.

4.138 Studies to evaluate the effectiveness of using additional barriers at the intakes were initiated at Bowline Point in April 1976. During the studies, stationary nets were placed in front of the intakes and located in a water velocity field where currents were weak enough to allow fish to move along the net or out of the area to avoid impingement. Preliminary baseline studies comparing the two Bowline Point units showed that, under normal operating conditions (no nets), Unit 1 impinged only 29 percent as many white perch and 38 percent as many striped bass as Unit 2 (Table 4-26). However, when the net was installed across the intake of Unit 2, impingement was reduced to the extent that Unit 2 impinged fewer fish than Unit 1. Comparison of 0.95 cm and 1.27 cm nets indicates that the smaller net is more effective at reducing impingement.

4.139 Closed Cycle Cooling in 1981. With the installation of closed cycle cooling at Bowline in 1981, the intake of Hudson River water will be reduced by 98 percent from the 784,000 gpm required for service and once-through cooling water to 16,000 gpm required for make-up and service water. Entrainment of phytoplankton zooplankton; and fish eggs, larvae, and juveniles will be reduced proportionately. Mortality, however, is expected to be 100 percent. The rate of impingment on the traveling screens would probably depend on the velocity conditions existing under the new pumping conditions, but is expected to be very low. The phytoplankton and zooplankton communities in the Hudson River near Bowline are unlikely to be materially affected by the quantity of organisms lost to makeup water.

4.140 Release of blowdown water from each of the cooling towers will be 3300 gpm at a temperature 19°F above ambient. If a diffuser is used for the discharge, measurable effects on the river ecosystem are unlikely. If a surface discharge is used, some localized effect on the aquatic system in the vicinity of the discharge may occur because of the elevated temperature of the effluent. The more sedentary bentic organisms would probably be affected the most.

4.141 It is expected that concentrations of chemicals in the blowdown water will all meet applicable state and Federal standards, and should have no appreciable effect on the receiving waters (see Water Quality section).

Impacts of Roseton Generating Station

4.142 Data available for an analysis of the impacts of Roseton Units 1 and 2 on the Hudson River are primarily for the years 1971 through 1976. Because the units did not begin full power operation until mid to late 1974 (Unit 2 in August and Unit 1 in late December), the data include both the effects of the nearby Danskammer plant (472 MWe, requiring 316,000 gpm cooling flow), which has been operational since 1951, and the Roseton Plant. The following discussion relies on data contained in Quirk, Lawler, and Matusky (1973), Lawler, Matusky, and Skelly (1975b, 1976b), Ecological Analysts (1976b), and Central Hudson Gas and Electric (1977).

4.143 Phytoplankton. Long term studies of the abundance and species composition of phytoplankton communities in the Roseton area

TABLE 4-26
SUMMARY OF IMPINGEMENT BARRIER NET STUDIES AT BOWLINE GENERATING STATION 1976-1977

		UNIT 1		UNIT 2			
SPECIES	n[b]	NET CONFIGURATION	NUMBER OF FISH IMPINGED	NET CONFIGURATION	NUMBER OF FISH IMPINGED	RATIO OF IMPINGEMENT AT UNIT 1 TO IMPINGEMENT AT UNIT 2	t-TEST FOR DIFFERENCE BETWEEN UNIT 1 AND UNIT 2
White Perch	29	No Net	265.38	No Net	915.63	0.29	-2.81**
	37	No Net	922.13	1.27-cm[d]	646.19	1.43	2.15*
	19	0.95-cm[d]	42.15	1.27-cm[d]	110.66	0.38	-5.28**
Striped Bass	22	No Net	21.48	No Net	93.55	0.23	-2.85**
	37	No Net	115.98	1.27-cm[d]	39.69	2.92	2.25*
	11	0.95-cm[d]	4.32	1.27-cm[d]	11.46	0.38	-3.06**

*Significant difference at α=0.05

**Significant difference at α=0.01

[a] Number of fish per million cubic meters of intake water

[b] Number of paired samples

[c] Two-sided paired t-test

[d] Mesh size of net

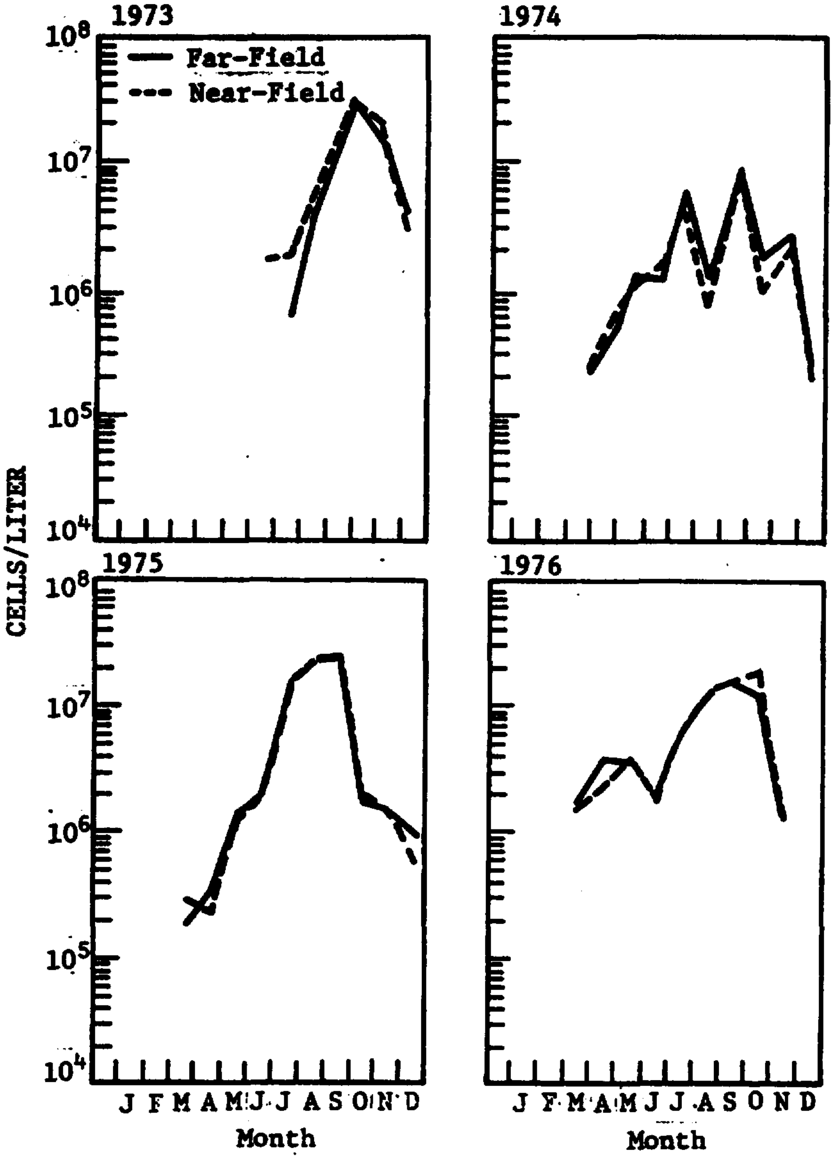
Source: Orange and Rockland, 1978.

have found no spatial distributions that could be related to plant operation (Central Hudson Gas and Electric, 1977). The quantity of phytoplankton entrained varied seasonally, with peak densitites occurring during late spring, summer, and early fall (see Figure 4-6). After entrainment, primary production rates were consistently suppressed when discharge temperatures exceeded 28 C. However, due to rapid dilution of discharge waters, no entrainment effects were detected beyond the plant discharge. Available data indicate that the operation of Roseton Units 1 and 2 should have only a slight effect on the phytoplankton community of the Hudson River in the vicinity of the power plant.

4.144 Zooplankton. Microzooplankton entrainment at Roseton varies seasonally with a spring maximum followed by a decrease during the summer and a second peak in early fall (Central Hudson Gas and Electric, 1977). The observed spatial distributions of microzooplankton around Roseton could not be correlated with entrainment effects of the power plant. Entrainment survival studies during 1975 and 1976 showed that microzooplankton generally sustained initial mortalities averaging 12 to 16 percent after passing through the plant (see Table 4-27 for sample results). Latent mortality after 48 hours averaged 6 to 10 percent. Mortality was independent of discharge temperature up to 35 C. Results from thermal tolerance laboratory studies suggest that substantial entrainment mortality from thermal effects alone should be expected only under full load and/or reduced pump flow conditions. From these lines of evidence, it is concluded that the effects of power plant entrainment on microzooplankton communities in the Roseton area are minimal.

4.145 Studies of macrozooplankton communities in the Roseton area have suggested no effects at the population or community level that could be associated with power plant entrainment. Survival studies have shown that macrozooplankton generally sustain entrainment mortalities averaging less than 10 percent (see Table 4-27 for sample results). Latent mortalities were insignificant at discharge temperatures below about 25 C but appear to have increased with discharge temperatures from 25 to 35 C. Thermal tolerance laboratory investigations using major macrozooplankton species predict that substantial mortality should occur only at temperatures above the range normally observed in the Roseton discharge, therefore little entrainment mortality is expected.

4.146 Benthic Animals. Macrobenthic communities may be affected directly by the discharge of a power plant, or the planktonic larvae of benthic species may be entrained with the power plant cooling water. Migrating benthic adults may periodically occur in the water column and at such times would also be susceptible to entrainment. The overall distribution and abundance of benthic populations in the Roseton area appear to be largely determined by



Source: Central Hudson Gas and Electric, 1977.

FIGURE 4-6
PHYTOPLANKTON ABUNDANCE IN THE ROSETON VICINITY
DURING 1973 THROUGH 1976

TABLE 4-27

IMMEDIATE ENTRAINMENT MORTALITY OF ZOOPLANKTON AT THE ROSETON GENERATING STATION*

SPECIES	PERCENT MORTALITY		
	SUMMER	FALL	WINTER
Total microzooplankton	0	10	15
Keratella cochlearis	0	0	0
Coppod nauplii	35	0	0
Eurytemora affinis	0	0	0
Halicyclops fosteri	0	0	17
Bosmina longirostris	0	0	0
Total macrozooplankton	0	0	0
Gammarus daiberi	0	0	0
Chaoborus punctipennis	5	0	0

*Zeros mean that no significant difference was found between immediate mortality in intake and discharge samples.

Source: Ecological Analysts, 1976b.

environmental factors (e.g., sediment type, salinity) that are independent of power plant operation (Central Hudson Gas and Electric, 1977). As a result, nearby benthic communities show considerable seasonal and temporal variation.

4.147 Design features of the Roseton discharge probably minimize its effect on the benthic community in the area of the discharge. Plume studies in 1975, when both units were operating, show that the heated plume rises to the river surface, so that temperature incre~~ases on the bott~~om in the vicinity are only several degrees fahrenheit. This small temperature increase is unlikely to affect benthic communities exposed to it. Some scour may occur in the immediate vicinity of the intake and discharge ports, but the total area affected should be very small in relation to total bottom area in the Roseton vicinity.

See pge 4-91

4.148 Many benthic species, especially dipterans such as *Chaoborus* sp., have planktonic larvae, which would be subject to entrainment mortality. Entrainment mortality has been found to be low for *Chaoborus* (see Table 4-27). Mortality of other dipterans has not been directly measured, but river populations are unlikley to be seriously affected. Normal stream drift would replace some larvae lost to entrainment.

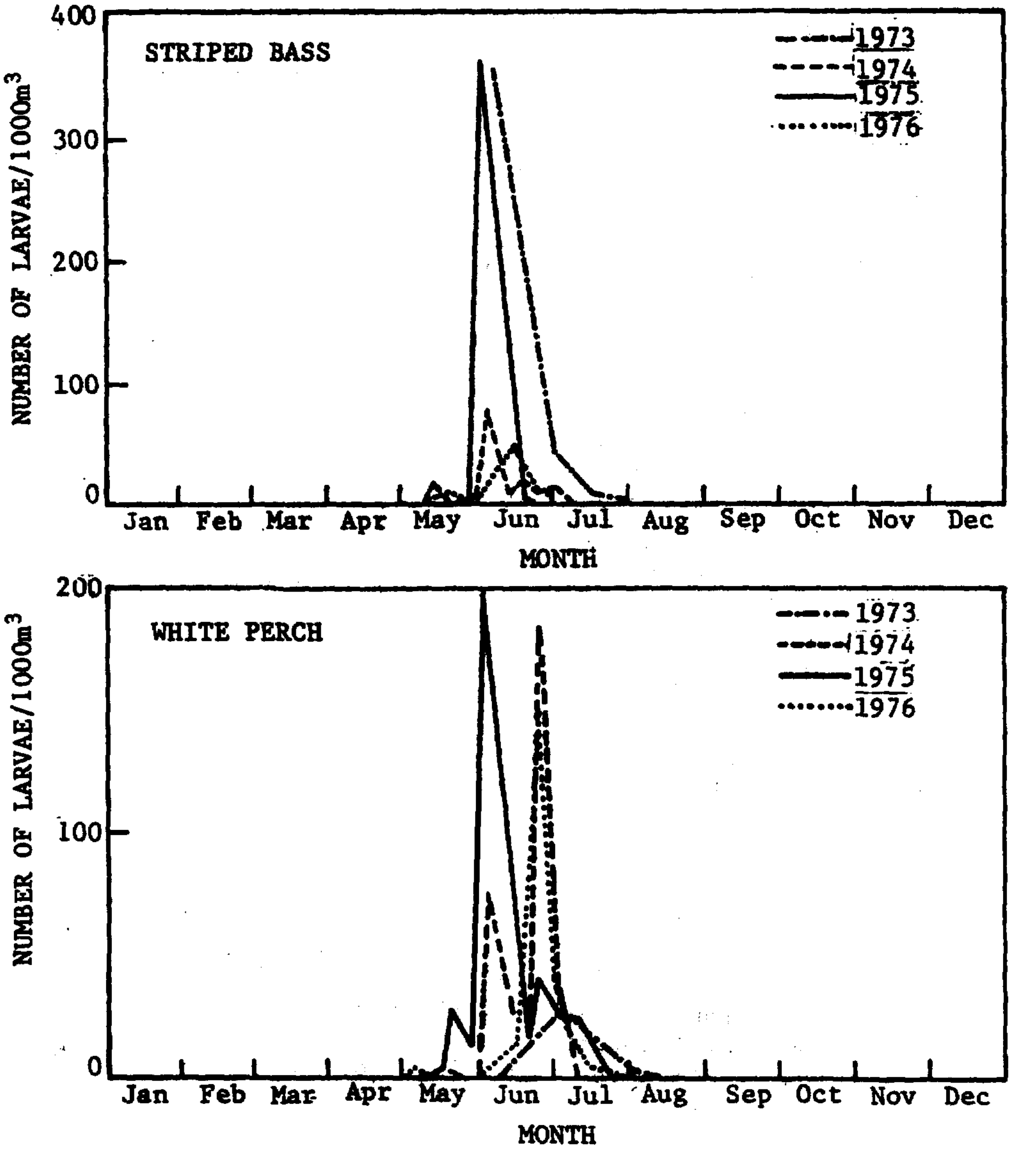
4.149 *Entrainment of Fish Eggs, Larvae, and Juveniles.* Cooling water for the Roseton Plant is taken directly from the Hudson River at River Mile 66 passed through the plant, and discharged at a location slightly downstream of the intake. Entrainment sampling has been carried out since 1973 using collecting devices at the plant intake and intermittent sampling has been conducted at the discharge to estimate the types and numbers of organisms passing through the plant. Fish eggs, larvae, and juveniles small enough to pass through the traveling intake screen (0.95 cm or 3/8 in) are entrained with the cooling water passing through the condenser and then are discharged back into the river. The primary factors that may cause adverse effects during entrainment are mechanical and thermal shock. The quantity of organisms entrained changes with seasonal variation in the abundances of fish eggs and larvae in surrounding waters, and with seasonal changes in flow rates of cooling water in the power plant.

4.150 In addition to the quantity of organisms entrained, the rates of immediate and latent entrainment mortality have been studied. Sublethal effects of passage through the power plant may also be important but are not well known. Because plant conditions vary depending on operational load, season, and equipment used, entrainment mortality varies with time. To assess the long range effect of entrainment by power plants, the loss due to entrainment must be compared to species standing stocks.

4.151 It is difficult to measure accurately the concentrations of eggs, larvae, and juveniles entrained by a power plant. Roseton data available to date are results from analysis of samples taken using 0.580 mm plankton nets (Central Hudson Gas and Electric, 1977). When nets are used to sample entrained organisms, the major sampling problems include net avoidance, clogging of nets, extrusion of eggs and larvae, and inaccurate measurement of water volume sampled. In an assessment of ichthyoplankton sampling programs used at Hudson River power plants, Carpenter (undated) concluded that Roseton sampling methods would tend to underestimate entrainment of fish eggs, larvae, and juveniles. The magnitude of the bias was not estimated.

4.152 Prevalent species collected at the Roseton Plant intake included white perch, striped bass, Atlantic Tomcod, Alosa spp. (probably alewife and blueback herring), and the bay anchovy. Alosa spp. eggs and larvae were entrained in greatest numbers. White perch eggs are demersal and adhesive and are generally not susceptible to entrainment (Figure 4-7). No white perch eggs were collected in 1974, those eggs collected in 1975 and 1976 were taken in greater numbers in bottom samples. Concentrations of white perch larvae fluctuated during 1974-1976, but peaked during May and June. The eggs of the striped bass were typically found on only a few collecting dates per year. The data suggest that late May and early June is the period of peak striped bass egg abundance at the Roseton intake. The abundance of striped bass juveniles was greatest during June. Atlantic tomcod eggs, although demersal and adhesive, have been collected in small number at Roseton during January through March. Maximum abundance of tomcod larvae was observed during March. Alosa spp. eggs and larvae were entrained in larger numbers than other species, occuring from April through July. No bay anchovy eggs were collected at Roseton during the sampling period. Bay anchovy larvae were collected from mid-July through mid-September. In addition, American eel, rainbow smelt, sunfishes, tesselated darter, white sucker, yellow perch, and various minnows and carps have occurred in entrainment samples at Roseton.

4.153 Entrainment mortality at the Roseton Plant has been estimated through comparison of survival rates in fish collected at the plant intake and discharge. Intake survival was used as a control because organisms collected at the intake were not entrained but were subjected to sampling and handling stress. The initial entrainment survival percentages (proportion surviving at intake divided by proportion surviving at discharge times 100) for selected entrained fish species in 1976 are presented in Table 4-28. Initial entrainment mortality for striped bass, white perch, and clupeids was generally 60 percent or greater for discharge temperatures below 30 C. At higher discharge temperatures, entrainment survival is



Source: Central Hudson Gas and Electric, 1977.

FIGURE 4-7
MEAN ABUNDANCE OF STRIPED BASS AND WHITE PERCH LARVAE AT THE ROSETON GENERATING STATION DURING 1973 THROUGH 1976

TABLE 4-28

ENTRAINMENT SURVIVAL OF ICHTHYOPLANKTON AT THE ROSETON PLANT DURING 1976

SPECIES	YOLK-SAC LARVAE		POST-YOLK SAC LARVAE		JUVENILES	
	TEMPERATURE (C)	PERCENT SURVIVAL	TEMPERATURE (C)	PERCENT SURVIVAL	TEMPERATURE (C)	PERCENT SURVIVAL
Striped bass	24.0-29.9	--	24.0-29.9	62	24.0-29.9	--
	30.0-32.9	--	30.0-32.9	55	30.0-32.9	--
	33.0-37.9	--	33.0-37.9	8	33.0-37.9	55
White perch	24.0-29.9	--	24.0-29.9	83(NS)	24.0-30.5	--
	30.0-32.9	--	30.0-32.9	38	30.6-33.5	51
	33.0-37.9	--	33.0-37.9	6	33.6-37.0	36
Clupeids	24.0-30.5	--	24.0-30.5	59	24.0-30.5	--
	30.6-33.5	--	30.6-33.5	14	30.6-33.5	16
	33.6-37.0	--	33.6-37.0	0	33.6-37.0	0

Note: Dashes indicate sample size at intake or discharge was less than 7. NS indicates survival at the discharge not significantly lower than that at the intake for a one-tailed t-test at the $\alpha = 0.05$ level.

Source: Central Hudson Gas and Electric, 1977.

generally low (0-55 percent). In most species studied, entrainment mortality appears to be related primarily to thermal stress. (Ecological Analysts, 1978b; Central Hudson Gas and Electric, 1977.) As found at the Bowline Point Plant, latent survival is expected to be somewhat less than initial survival, but was not measured at Roseton.

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4.154 Central Hudson Gas and Electric (1977) has calculated estimates of entrainment-related loss of fish eggs, juveniles, and larvae based on species standing crops, rates of entrainment, and survival rates. These estimates are expressed as the number of larvae killed by entrainment in a given year divided by the standing crop of the larvae between River Mile 50 and River Mile 70. Losses for the following species have been estimated:

SPECIES	PERCENT LOSS OF STANDING CROP FROM ENTRAINMENT[a] 1974	1975	SOURCE
White Perch	0.49	1.75	Central Hudson Gas and Electric (1977)
Striped Bass	--	3.5	McFadden (1977)
Alosa spp.	0.54	1.10	Central Hudson Gas and Electric (1977)

[a] standing crop between River Mile 50 and River Mile 70.

Quantitative estimates have not been made for other species affected, such as the bay anchovy and Atlantic tomcod.

4.155 Fish Impingement. Eight traveling screens are utilized at the Roseton Generating Station cooling water intake to prevent fish from entering the plant. The traveling screens are constructed of 0.95 cm (3/8 inch) mesh and are cleared of trapped fish and debris with a spray of water. A disposal trough returns screen washings to the Hudson River. When impingement sampling is carried out, fish retained on the screen are sorted from the debris and collected for study. A weekly sampling program was initiated in July 1973 and data are now available from samples taken through 1976.

4.156 A total of 41 species were collected from the Roseton intake screens between July 1973 and December 1976. Based on four years of data presented in Table 4-29, white perch (43-71 percent) and blueback herring (5-37 percent) were most numerous among the impinged assemblage. Spottail shiner, Atlantic tomcod, alewife, bay anchovy and white catfish each represented 2 to 5 percent of the individuals when averaged over the three year period. Striped bass

TABLE 4-29

TOTAL ABUNDANCE AND PERCENT COMPOSITION OF ALL FISH SPECIES IN IMPINGEMENT COLLECTIONS FROM THE ROSETON GENERATING STATION FROM 1973 THROUGH 1976

	YEAR								
	1973		1974		1975		1976		MEAN PERCENT OF TOTAL FOR 1973 THROUGH 1976
COMMON NAME	NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	
White perch	8798	42.75	5654	61.77	18411	49.10	15136	71.10	56.20
Blueback herring	7676	37.30	485	5.30	9549	25.47	1404	6.60	18.66
Spotail shiner	334	1.62	700	7.65	1902	5.07	1107	5.20	4.88
Atlantic tomcod	78	0.38	860	9.40	613	1.63	1116	5.29	4.18
Alewife	1435	6.97	254	2.78	1967	5.25	329	1.55	4.13
Bay anchovy	1248	6.06	515	5.62	408	1.09	333	1.56	3.58
White catfish	190	0.92	234	2.56	1059	2.82	406	1.91	2.06
Striped bass	416	2.02	86	0.94	207	0.55	89	0.42	0.98
Gizzard shad	15	0.07	25	0.27	736	1.96	333	1.56	0.96
Bluegill	118	0.57	20	0.22	729	1.94	53	0.25	0.74
Pumpkinseed	16	0.08	77	0.84	267	0.71	273	1.28	0.72
Rainbow smelt	97	0.47	14	0.15	445	1.19	74	0.35	0.54
Hogehoker	74	0.36	40	0.44	243	0.65	129	0.61	0.52
American shad	19	0.09	28	0.31	342	0.91	51	0.24	0.39
Tessellated darter	6	0.03	19	0.21	101	0.27	153	0.72	0.31
American eel	5	0.02	27	0.29	134	0.36	85	0.40	0.27
Golden shiner	29	0.14	38	0.41	57	0.15	35	0.16	0.22
Goldfish	12	0.06	23	0.25	51	0.14	47	0.22	0.17
Brown bullhead	3	0.01	16	0.17	35	0.09	32	0.15	0.11
Yellow perch	-	-	11	0.12	52	0.14	31	0.15	0.10
Bluefish	-	-	1	0.01	109	0.29	-	-	0.08
Banded killifish	3	0.01	6	0.07	31	0.08	34	0.16	0.08
Largemouth bass	-	-	2	0.02	14	0.04	6	*	0.02
Atlantic sturgeon	3	0.01	4	0.04	9	0.02	2	*	0.02
Redbreast sunfish	-	-	4	0.04	6	0.02	4	*	0.01
Black crapple	3	0.01	2	0.02	-	-	3	*	<0.01
White crapple	-	-	-	-	-	-	-	-	<0.01
Shortnose sturgeon	-	-	1	0.01	-	-	-	-	<0.01
Central mudminnow	-	-	-	-	-	-	1	*	<0.01
Carp	-	-	-	-	4	0.01	-	-	<0.01
Emerald shiner	-	-	-	-	-	-	1	*	<0.01
Spotfin shiner	-	-	-	-	1	*	-	-	<0.01
White sucker	-	-	2	0.02	-	-	-	-	<0.01
Yellow bullhead	-	-	-	-	3	*	-	-	<0.01
Mummichog	-	-	-	-	-	-	1	*	<0.01
Fourspine stickleback	-	-	-	-	-	-	1	*	<0.01
Threespine stickleback	-	-	2	0.02	4	0.01	1	*	<0.01
White bass	-	-	-	-	1	*	4	*	<0.01
Rock bass	1	*	-	-	3	*	2	*	<0.01
Warmouth	-	-	-	-	1	*	-	-	<0.01
Spot	-	-	-	-	-	-	2	*	<0.01
TOTAL NUMBER COLLECTED	20579	99.9	9153	99.9	37495	99.9	21288	99.8	
TOTAL NUMBER OF SPECIES	23		30		33		33		

- None Collected
* Less than 0.01 percent

Source: Central Hudson Gas and Electric, 1977.

accounted for less than 1 percent of the individuals during the same period. Because of the seasonal nature of impingement rates (see Figure 4-.8), for most species the annual total number of fish impinged is sensitive to the relative magnitudes of the flow rate and the impingement rate at a given time. No long-term trends in numbers of fish impinged are evident and yearly changes in impingement probably reflect natural fluctuations in populations of fish species.

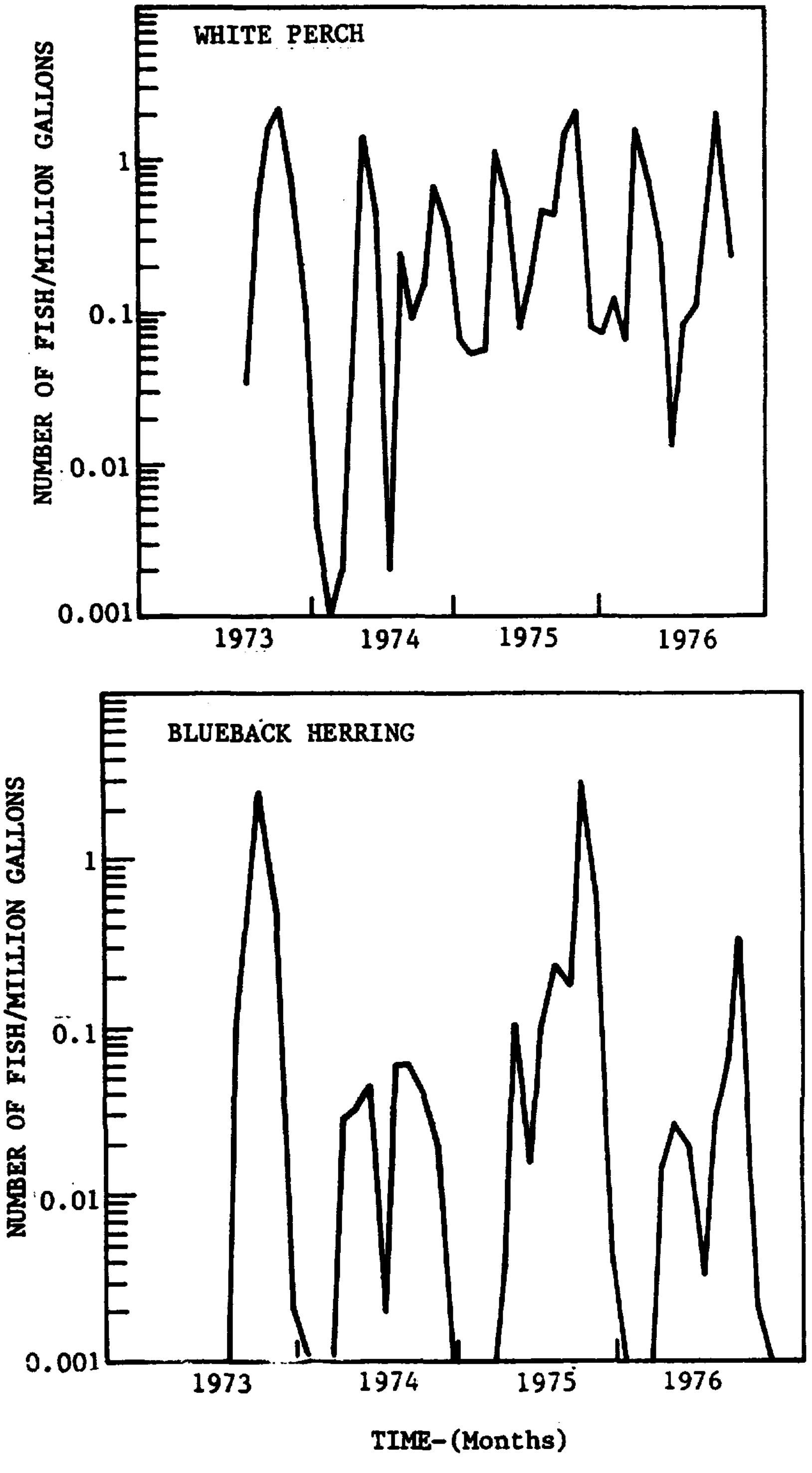
4.157 In general, young of the year and yearlings tend to dominate impinged assemblages. Many species show increased impingement rates at night. Impinged fish do not seem to represent the less fit or weaker individuals.

4.158 After impingement of white perch on the traveling screen and discharge of the fish into the Hudson River, the probability of re-impingement was highest at mid-flood tide (37 percent) and lowest at mid-ebb (1.7 percent). Nearly all re-impinged fish were captured within 1.5 hours of release. The combined re-impingement rate for live white perch released over all tidal stages was 23 percent.

4.159 Impingement survival studies were conducted at the Roseton Generating Plant during 1975 and 1976. Initial and latent survival (after 96 hours) were examined to determine the overall effects of the impingement process on affected individuals. Impingement survival at Roseton varies with the species of fish and the screenwashing frequency. Sample data presented in Table 4-30 demonstrate the relatively high initial survival and substantially lower 96 hour survival observed for white perch and striped bass. Blueback herring, alewife, centrarchids, and tomcod appeared more sensitive to impingement than <u>Morone</u> spp. Continuous screenwashing resulted in higher survival than intermittent wash.

4.160 The impact of fish impingement at the Roseton Plant can be partially assessed by comparing the number of fish lost through impingement to the number of fish in the source population. The fraction lost through impingement can be calculated by dividing the impingement loss value by the size of the population standing crop between River Mile 50 and River Mile 70. To provide conservative estimates of impingement effects, 100 percent mortality of impinged fish is assumed. Several sampling problems are involved, and a number of assumptions must be made in estimating total numbers of fish impinged and the population standing crop. The procedures that have been followed in making these estimates are summarized by Barnthouse and Van Winkle (1979) and Van Winkle and Barnthouse (1979). Under the assumption used in Central Hudson Gas and Electric (1977), the population loss due to Roseton impingement of four selected species ranged from 0.001 percent (bay anchovy) to 0.5 percent (white perch) in 1975 and 1976 (see Table 4-31).

over
estimate
of impact



Source: Central Hudson Gas and Electric, 1977.

FIGURE 4-8
SEASONAL VARIATION IN RATES OF IMPINGEMENT AT THE ROSETON GENERATING STATION FOR WHITE PERCH AND BLUEBACK HERRING

TABLE 4-30

SUMMARY OF FISH IMPINGEMENT SURVIVAL AT THE ROSETON GENERATING STATION DURING THE FALL OF 1975[a]

SPECIES	NUMBER OF FISH	PROPORTION ALIVE INITIALLY	PROPORTION ALIVE AFTER 96 HOURS
	CONTINUOUS WASH[b]		
White perch	201	0.83	0.08
Striped bass	4	0.50	0.25
Blueback herring	16	0.25	0.00
Alewife	8	0.25	0.00
Centrarchids	0	--	--
Atlantic tomcod	4	0.25	0.00
	2-HOUR WASH[b]		
White perch	667	0.60	0.01
Striped bass	11	0.56	0.00
Blueback herring	5,833	0.06	0.00
Alewife	162	0.16	0.00
Centrarchids	25	0.40	0.12
Atlantic tomcod	13	0.39	0.08
	4-HOUR WASH[b]		
White perch	239	0.22	0.00
Striped bass	5	0.00	0.00
Blueback herring	327	0.03	0.00
Alewife	54	0.00	0.00
Centrarchids	5	0.60	0.00
Atlantic tomcod	2	0.00	0.00
	6-HOUR WASH[b]		
White perch	684	0.25	0.00
Striped bass	6	0.00	0.00
Blueback herring	4,476	0.06	0.00
Alewife	169	0.06	0.00
Centrarchids	0	--	--
Atlantic tomcod	0	--	--

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[a] Control fish collected from the Hudson River with beach seines. Only striped bass and white perch were maintained. Survival was generally at or near 100 percent for the 96-hour holding period.

[b] Washwater pressure was 96 psi.

Source: Central Hudson Gas & Electric (1977)

TABLE 4-31

ESTIMATIONS OF STANDING CROP LOSS THROUGH ROSETON IMPINGEMENT DURING 1975-1976[a]

SPECIES	PERCENT[b] OF STANDING CROP LOST THROUGH ROSETON IMPINGEMENT 1975	1976
White Perch	0.2 - 0.3	0.3 - 0.5
Blueback Herring	0.12 - 0.36	0.07 - 0.20
Atlantic Tomcod	0.01 - 0.02	0.03 - 0.05
Bay Anchovy	0.001 - 0.001	0.02 - 0.03

[a] Standing crop between River Mile 50 and River Mile 70.

[b] Range shown is for 30% and 50% sampling gear efficiency.

Source: Central Hudson Gas and Electric, 1977.

4.161 Several factors have been identified that may bias impingement estimates at Hudson River Power Plants (Barnthouse, 1979). These biases have been discussed in the section on impingement at the Bowline Point Power Station. In an assessment of impingement estimate bias at the Roseton Plant, Barnthouse concluded that the following adjustment factors should be applied to Roseton impingement estimates presented in Central Hudson Gas and Electric (1977).

- Estimate of clupeid impingement should be increased by a factor of 1.4.

- Estimates of Atlantic tomcod impingment from September to April should be reduced by a factor of 0.6.

- Estimates of white perch and striped bass impingement were not found to be biased in excess of 20 percent, the acceptable error limit used by Barnthouse.

Cumulative Impacts of Present Generating Stations on the Hudson River Ecosystem

4.162 The overall effect of the simultaneous operation of the Bowline Point, Lovett, Indian Point, Roseton, and Danskammerpower generating stations on the ecosystem of the Hudson River estuary downstream of the dam at Troy are discussed in this section. The effects of the recently constructed Bowline Point, Indian Point, and Roseton plants, are considered in more detail because the other older plants have been in operation long enough so that their effects may already be reflected in the available baseline data.

Phytoplankton

4.163 Several years of sampling in the vicinity of the Bowline Point, Lovett, Indian Point, Roseton, and Danskammer power plants has revealed no significant local changes in the phytoplankton community attributable to the operation of these generating stations. However, these data were not obtained under full-power conditions for all proposed power plants along the entire river. Model estimates of the temperature distribution along the river for April through September under full power conditions and once-through cooling for the Albany, Roseton, Danskammer, Indian Point, Lovett, Bowline Point, and 59th Street power stations indicate that an overall temperature increase of about 1 to 3 F will occur for a few miles downstream from the Bowline generating station (Appendix E). The average temperature increase is variable with distance from a discharge source and is highest in the Indian Point-Bowline Point region.

4.164 The effects on the phytoplankton community of a year-round increase in temperature of only a few degrees is difficult to predict. If any alteration occurs it is likely to be most prevalent during the seasonal extremes of temperature. During a mild winter, the switch to diatom dominance may not be as prominant. During the warmest summer months, an additional heat load would favor blue-green algae, a pattern that already naturally occurs in the estuary (see Figure 2-18). Some changes in species composition are possible. Alterations, if any, are most likely to occur in the Bowline Point-Indian Point region, where water temperature will be increased the most. Ecological Analysts (1977b) have investigated the cumulative effects of Roseton, Indian Point, and Bowline Point generating stations on Hudson River phytoplankton. In this study, it is concluded that no adverse effects of entrainment on phytoplankton communities have been detected or are predicted. Peak discharge temperatures may result in slight reductions (10-20 percent) in algal productivity at some sites. However, no reductions should be detectable beyond the immediate vicinity of the power plant discharges.

This assumes the whole water body is affected by the heat + that's not so.

Microzooplankton

4.165 Studies of entrainment mortality of microzooplankton have produced mixed results. At Bowline Point and Indian Point, mortality increased during the summer, especially for copepods. At Roseton, copepod nauplii experienced a significant mortality during the summer.

4.166 Effects of entrainment mortality on the overall river population depend on the total number of microzooplankton lost from the river and the ability of the population to replace those lost. Sampling programs at Bowline Point, Lovett, Indian Point, and Danskammer have found no changes in the zooplankton communities of these areas attributable to power plant operation. An investigation performed by Ecological Analysts (1977b) concluded that no adverse impacts on Hudson River microzooplankton communities have been detected or are predicted to result from entrainment at Bowline Point, Roseton, and Indian Point generating stations. The combination of modest entrainment mortality and rapid regeneration times typical of microzooplankton species makes it unlikely that this community will be significantly influenced directly by entrainment.

4.167 As with phytoplankton, the effect of a small year-round increase in average water temperature on microzooplankton is difficult to predict. Some species composition changes are possible during years of exceptionally warm ambient water temperatures. Species changes could also take place if phytoplankton species composition is altered by warmer temperatures. Alterations, if any, are most likely to occur in the Bowline Point-Indian Point region, where water temperature will be raised the most.

Macrozooplankton

4.168 With the exception of Neomysis americana (oppossum shrimp), measured entrainment mortality of the major macrozooplankton species is very low. Neomysis, a saltwater species, is susceptible to entrainment only by Bowline Point, Lovett and Indian Point when saline water is in their vicinity during late summer and fall. Neomysis is usually abundant only when salinity is one part per thousand or greater.

4.169 Apparently, entrainment mortality of Neomysis is only a problem at Indian Point when river temperatures are warmest. Limited data at Bowline Point show that Neomysis was entrained in small numbers and experienced no detectable mortality. The additional mortality within the river population of Neomysis represented by entrainment losses at Indian Point has not been calculated, but are likely to be small. An investigation performed by Ecological Analysts (1977b) concluded that the operations of once-through cooling systems at Bowline Point, Indian Point, and Roseton generating stations would have no adverse effects on the macrozooplankton communities of the Hudson River, nor on the organisms that feed on these communities. It is unlikely that operation of the power plants on the estuary will significantly affect the macrozooplankton community.

Benthic Animals

4.170 The use of bottom diffusers at Bowline and Roseton and the arrangements for maintaining the plume on the surface at Indian Point reduce the direct impact of the thermal discharges on the benthic community in the estuary. No widespread modifications of the benthos attributable to the operation of the power plants have been found in several years of field sampling in the vicinity of these plants (Ecological Analysts 1977b). Some local effects of scouring at the intake and discharge structures are possible.

4.171 No overall quantitative estimates are available on the entrainment mortality of planktonic stages of benthic organisms. Limited data on Chaoborus punctipennis at Roseton suggest very low mortality for larvae of this dipteran species. Some mortality can be expected for other species as well. The effect of this entrainment mortality on the benthic community is unknown at this time, but is likely to be quite small.

4.172 The overall increase in average water temperature that may occur because of the interaction of discharge plumes along the river, especially in the Bowline Point-Indian Point region (Barnthouse et al., 1977; Appendix E) may have only a small effect, if any, on the benthic community. The general tendency for the warmest water to remain near the surface will prevent benthic animals from experiencing the main impact of the thermal effluents. By the time mixing of the heat load into deeper water layers has taken place, heat losses to the atmosphere and cooling by dilution with ambient water probably will have reduced the average temperature increase experienced by the bottom animals to 1 F or less.

inconsistent with discharge from Roseton the following bottom only several layers. see pg 4-78

Entrainment of Fish Eggs, Larvae, and Juveniles

4.173 An initial step in predicting how entrainment mortality will affect a fish population in the long term is to estimate the conditional entrainment mortality imposed by power plants. Conditional entrainment mortality is defined as the percentage of eggs and larvae spawned that year that would have been killed if the only cause of death was entrainment resulting from operation of the power plants. Conditional entrainment mortality may be estimated by using measures of entrainment survival, numbers of organisms entrained, and the number of organisms in the pool population. None of these parameters has been measured directly with a high degree of accuracy. Therefore, it is necessary to make assumptions and perform extrapolations to transform available data into estimates of the required parameters. Several approaches have been used to achieve this end. Utilities and their consultants have used a hydrodynamic transport model, which infers entrainment abundances from ratios of plant to river abundances of entrainable organisms (Lawler and McFadden, 1977). In addition, the Utilities have used a simpler approach, in which the number of organisms entrained (estimated from plant samples and flow rate measurements) is divided by the average standing crop of entrainable organisms during the specific time period (estimated from river sampling) (Orange and Rockland, 1977; Central Hudson Gas and Electric, 1977).

4.174 The major sources of bias and inaccuracy in these approaches include grouping entrainable organisms across all entrainable life stages and assumptions about the relative sampling efficiencies of plant and river sampling techniques. A discussion summarizing the limitations of these approaches is provided in Boreman et al. (1979). The Empirical Transport Model (ETM) has been selected by the U.S. Environmental Protection Agency and their consultants to remedy some of these problems in an attempt to approximate conditional entrainment mortality more closely (Boreman et al., 1978).

4.175 Estimates of conditional entrainment mortality are presented in Table 4-32. Several ETM runs were made for each fish population. Runs using conditions existing in 1974 and 1975 are presented to compare ETM estimates to those made by Utilities. Runs using projected cooling water requirements provide a basis for determining the probable impact of Hudson River power plants with expected once-through and closed-cycle operating conditions. Runs using expected future requirements are necessary because additional units have become operational since 1974-1975 (e.g., Roseton, Indian Point Unit 3), and other units are expected to be phased out over the next few years (e.g., units at Lovett, Danskammer, and Indian Point).

4.176 Estimates of conditional entrainment mortality by the U.S. Environmental Protection Agency (Table 4-32) are somewhat greater than but generally similar to estimates of the Utilities for the impacts of Roseton, Indian Point 3, and Bowline Point in 1974 and 1975, the only case for which comparable estimates have been made. The largest impact is predicted for bay anchovy because this species has very poor survival after passing through power plant cooling systems. Conditional mortality predicted for striped bass, white perch, and <u>Alosa</u> spp. due to the operation of all power plants was estimated to be in the range of 10 to 20 percent for 1974 and 1975.

4.177 Projections of the magnitude of conditional entrainment mortality that could prevail under conditions of once-through cooling in the future have been made only by the U.S. Environmental Protection Agency (Table 4-32). In general, conditional entrainment mortality would increase on the order of 3 percent over 1975 estimates for striped bass and white perch and about 10 percent for American shad. Mortality would still be in the range of 15 to 22 percent. Conditional entrainment mortality for bay anchovy, Atlantic tomcod, and <u>Alosa</u> spp. would not change greatly. Mortality to bay anchovy could be very great, although the range of estimates is also large.

4.178 The contribution of each power plant to total conditional mortality with once-through cooling is difficult to estimate because such a breakdown is not given in published reports or hearing testimony. However, a rough estimate based on data contained in McFadden and Lawler (1977, Table) and Table 4-32 suggests that for striped bass and white perch the breakdown could be on the order of the following:

TABLE 4-32

ESTIMATES OF CONDITIONAL ENTRAINMENT MORTALITY RESULTING FROM POWER PLANTS ON THE HUDSON RIVER (percent)

	ESTIMATES OF PAST IMPACTS				EPA PROJECTIONS OF FUTURE YEARLY IMPACTS[b]	
	1974		1975			
SPECIES	EPA[b]	UTILITIES	EPA[b]	UTILITIES	ONCE-THROUGH COOLING[c]	CLOSED-CYCLE COOLING[d]
	ALL POWER PLANTS[e]				ALL POWER PLANTS[e]	
Striped bass	11-15	NE	18	NE	16-22	4-8
White perch	11-12	NE	13	NE	16-17	3-4
Alosa spp.	4	NE	6-11	NE	6-11	1-4
American shad	14	NE	NE	NE	21	4
Atlantic tomcod	NE	NE	5-8	NE	7-8	2
Bay anchovy	54-78	NE	35-46	NE	44-79	13-25
	ROSETON[g], INDIAN POINT 2, AND BOWLINE POINT ONLY[f]				ROSETON, INDIAN POINT 2 AND 3, AND BOWLING POINT ONLY[f]	
Striped bass	7-8	8	13	12	14-17	2-2
White perch	7-8	6	9-10	6	13-15	1
Alosa spp.	2	NE	4-6	NE	5-8	<1
American shad	9	2	NE	NE	18	1
Atlantic tomcod	NE	NE	4-7	4	6-8	2
Bay anchovy	36-65	NE	26-37	NE	38-75	2-8

NE = no estimate made.

[a] Mortality that would result if only factor causing death was power plant operation.

[b] Estimated using the Empirical Transport Model.

[c] Once-through cooling at all power plants.

[d] Closed-cycle cooling at Roseton, Indian Point, and Bowline. Lovett and Danskammer with once-through cooling.

[e] Total mortality resulting from operation of all power plants.

[f] Mortality resulting from operation of these plants only. Difference between e and f is mortality resulting from operation of Danskammer and Lovett.

[g] Unit 2 operational in September 1974, Unit 1 operational in December 1974.

Power Plant	Percent Contribution to Total Entrainment Conditional Mortality	
	Striped Bass	White Perch
Bowline	14	12
Indian Point 2 and 3	43	59
Roseton	19	12
Danskammer and Lovett	24	18

If these estimates are approximately correct, then the operation of the Indian Point station accounts for about one-half of the total impact of entrainment of all power plants. The Bowline Point and Roseton stations each account for only about 10 to 20 percent of total conditional mortality.

4.179 Should closed-cycle cooling be installed at Bowline Point, Indian Point, and Roseton, the conditional mortality due to operation of all power plants would drop to a low level (Table 4-32). One-half or more of the remaining impact would occur at the Lovett, Danskammer, and Albany facilities, which are exempt from any requirement for modification of their cooling systems.

Impingement of Fish

4.180 During the years 1973 through 1977, it is estimated that a total of 1.4 to 3.6 million white perch, striped bass, American shad, alewife, blueback herring, bay anchovy, and Atlantic tomcod were impinged annually at Bowline Point, Roseton, Indian Point, Danskammer, and Lovett Generating Stations (see Table 4-33 and McFadden, 1978). Only the data for 1977 and 1977 in Table 4-33 represent conditions of full-scale commercial operation of all units that will continue to be on-line for the near future (Roseton, Bowline Point, Indian Point Units 2 and 3, Lovell, Danskammer and Albany.) With the exception of striped bass and alewifes, the greatest number of fish are impinged at Indian Point. Impingement of alewifes is spread fairly evenly among all plants except Lovett. Bowline Point and Indian Point account for most of the impingement of striped bass.

4.181 Although the greatest number of fish were impinged in 1977, there is no clear trend of increasing impingement through the years. The 1977 maximum is related to increased impingement of all species at Indian Point during that year. The increase at Indian Point was due to a greater volume of water passing through the plant combined with a higher rate of impingement (No./water volume, i.e., more fish in the water). With the continued full scale operation of the Indian Point Generating Station, it may be expected that this

SPECIES AT HUDSON RIVER POWER PLANTS DURING 1973 THROUGH 1977

POWER PLANT	1973	1974	1975	1976	PERCENT OF TOTAL	1977	PERCENT OF TOTAL
	TOTAL INDIVIDUALS IMPINGED[a]						
			WHITE PERCH				
Bowline[b]	99,700	357,500	368,300	275,700	28	149,600	9
Indian Point[c]	83,900	367,800	299,300	440,600	45	1,094,600	68
Lovett	61,100	87,300	82,800	46,100	5	81,000	5
Roseton	9,100[d]	37,300	139,400	104,200	11	132,000	8
Danskammer	110,550	84,300	98,200	117,700	12	140,800	9
TOTAL	364,300	934,200	988,000	984,300		1,598,000	
			STRIPED BASS				
Bowline[b]	9,300	87,600	81,400	25,700	73	19,100	35
Indian Point[c]	1,800	6,300	6,000	6,100	17	27,700	51
Lovett	5,500	9,700	5,300	1,600	5	2,700	5
Roseton	500[d]	600	1,400	600	2	2,700	5
Danskammer	19,000	6,300	2,600	1,400	4	1,900	4
TOTAL	36,100	110,500	96,700	35,400		54,100	
			AMERICAN SHAD				
Bowline[b]	200	4,800	1,200	1,200	15	1,400	7
Indian Point[c]	19	1,500	1,100	4,200	54	12,700	66
Lovett	400	1,000	500	45	<1	100	<1
Roseton	21[d]	300	2,300	400	5	2,400	13
Danskammer	1,300[d]	2,400	2,500	2,000[d]	26	2,600	14
TOTAL	1,900	10,000	7,600	7,800		19,200	
			ALEWIFE				
Bowline[b]	20,500	22,100	8,400	5,500	25	35,900	23
Indian Point[c]	1,200	6,400	4,200	3,500	16	58,600	37
Lovett	8,700	3,500	4,900	600	3	1,900	1
Roseton	1,900[d]	1,500	12,200	2,400	11	37,300	24
Danskammer	148,900	31,400	29,800	9,900	45	24,600	16
TOTAL	181,200	64,900	59,500	21,900		158,300	
			BLUEBACK HERRING				
Bowline[b]	18,800	45,000	25,600	5,400	2	33,700	5
Indian Point[c]	1,000	37,500	155,800	258,300	89	637,400	85
Lovett	9,000	13,800	7,400	400	<1	800	<1
Roseton	6,400[d]	2,700	78,900	10,400	4	46,400	6
Danskammer	29,200	13,300	100,100	14,200	5	30,100	4
TOTAL	64,400	112,300	367,800	288,700		748,400	
			BAY ANCHOVY				
Bowline[b]	4,400	4,900	3,700	3,800	20	7,400	4
Indian Point[c]	11,900	95,000	96,000	12,100	64	146,900	78
Lovett	4,800	4,700	1,600	400	2	1,200	<1
Roseton	1,100[d]	3,400	2,300	2,400	13	31,200	17
Danskammer	22,200	2,300	2,100	100	<1	1,300	<1
TOTAL	44,400	110,300	105,700	18,800		188,000	
			ATLANTIC TOMCOD				
Bowline[b]	12,600	13,900	16,100	4,600	5	12,800	2
Indian Point[c]	28,300	375,700	78,600	34,200	34	747,800	92
Lovett	59,500	21,500	4,500	1,300	1	5,200	<1
Roseton	300[d]	4,300	4,800	7,200	7	19,500	2
Danskammer	647,000	155,900	46,900	54,600	54	26,900	3
TOTAL	747,700	571,300	150,900	101,900		812,200	
SUM OF ALL SPECIES	1,440,000	1,913,500	1,776,200	1,458,800		3,578,200	

[a] Total has been rounded to nearest 100.

[b] Unit I started commercial service in October 1972; Unit II started commercial service in May 1974.

[c] Sum of 3 Indian Point Units--Unit I was shut down in October 1974; Unit II started operation in June 1972; Unit III was operated March-December 1974 and started up again in January 1976.

[d] No sampling prior to July 1973. Limited plant operation until fall of 1974. Unit 2 in full commercial operation in September 1974, Unit 1 in December 1974.

Source: McFadden (1978)

plant will remain the primary impinger among Hudson River power plants.

4.182 Information relating numbers of fish impinged must be assessed relative to the total pupulation size, natural mortality rates, reproduction capability, and life history biology of a species to determine the significance of the impact from impingement. Conditional impingement mortality may be used as an initial measure of impingement impact on a population of fish. Conditional impingement mortality is defined as the percentage of juvenile fish of each species spawned that year that would have been killed if the only cause of death to juvenile fish was impingement resulting from operation of the power plants. The usefulness of this measure is that it estimates the impingement-related fractional reduction in year class abundance in the absence of other sources of mortality and compensation. Estimates of coniditonal mortality very depending on assumptions made in developing input data and scenarios (Barnthouse, 1979).

4.183 Estimates of conditional impingement mortality resulting from the operation of the Roseton, Bowline, and Indian Point stations are available only for conditions prevailing in 1974 and 1975 (Table 4-34). Neither Bowline Point nor Roseton were fully operational during 1974. In 1975, Indian Point Unit 3 was not operational. Based on these limited data, however, it can be seen from Table 4-34 that conditional impingement mortality, even with once-through cooling at all three of these power plants, was relatively low except for white perch. In most cases, the Utilities' estimates fell within the ranges independently estimated by the U.S. Environmental Protection Agency (Barnthouse and Van Winkle, 1979).

4.184 Seasonal and spatial variations in riverwide fish impingement are evident (Tables 4-35 and 4-36). White perch were impinged in greatest quantities at downriver power plants (Bowline, Lovett and Indian Point) during January through April, Roseton and Danskammer farther upstream from April through June or July, and once again in early fall, and at the Albany station (farthest power plant upriver) from June through October. Blueback herring exhibited some spring and strong fall impingement at the downriver plants and spring, summer, and fall impingement at the upriver plants. The impingement rate of alewifes was greatest at the upriver plants, and occurred almost exclusively during summer and early fall. Bay anchovy, a species found only in more saline water, was impinged strongly during mid- and late summer at the downriver plants. Very large impingement rates for Atlantic tomcod occurred at Danskammer during the winter. Downriver, impingement was greatest during the summer, occurring principally at Indian Point. A lesser peak in impingement occurred during the winter. The impingement patterns for

TABLE 4-34

ESTIMATES OF CONDITIONAL IMPINGEMENT MORTALITY (PERCENT) FOR THE 1974 AND 1975 YEAR CLASSES OF WHITE PERCH, STRIPED BASS, AND ATLANTIC TOMCOD, ASSUMING THREE ALTERNATIVE CLOSE-CYCLE COOLING CONFIGURATIONS

	CONFIGURATION					
	1[a]		2[b]		3[c]	
	LOW	HIGH	LOW	HIGH	LOW	HIGH
White perch (1974)						
Maximum range	2.7	15.0	3.0	17.7	4.2	23.7
Probable range	3.1	12.8	3.6	14.3	4.9	19.5
White perch (1975)						
Maximum range	1.3	4.2	1.9	6.1	2.4	7.8
Probable range	2.0	4.2	2.9	6.1	3.6	7.8
Striped bass (1974)	0.3	2.3	0.3	2.4	1.0	8.1
Striped bass (1975)	0.1	1.3	0.1	1.3	0.3	2.4
Atlantic tomcod (1974)	0.4	1.8	0.4	1.9	0.4	1.9
Atlantic tomcod (1975)	0.1	0.3	0.1	0.4	0.1	0.4

[a] Closed-cycle cooling at Bowline, Indian Point, and Roseton.

[b] Closed-cycle cooling at Bowline, and Indian Point; once-through cooling at Roseton.

[c] Closed-cycle cooling at Indian Point; once-through cooling at Bowline and Roseton.

Source: Barnthouse and Van Winkel, 1979.

TABLE 4-35

PERIODS OF GREATEST IMPINGEMENT FOR SEVERAL FISH SPECIES AT POWER PLANTS ON THE HUDSON RIVER ESTUARY

	POWER PLANT		
SPECIES	BOWLINE LOVETT INDIAN POINT	ROSETON DANSKAMMER	ALBANY
White Perch	Winter and Early Spring	Spring and Early Summer, Early Fall	Summer and Early Fall
Blueback Herring	Spring, Fall	Spring through Fall	Spring through Fall
Alewife		Summer and Early Fall	Summer and Early Fall
Bay Anchovy	Mid-to-late Summer		
Atlantic Tomcod	Summer, Winter	Winter	
Striped Bass	Winter and Early Spring	Summer and Early Fall	Summer and Early Fall

Source: Data presented in Barnthouse et al., 1977. Tables A5.4-1 through A5.4-5.

TABLE 4-36

MONTHS OF GREATEST AND LEAST IMPINGEMENT OF STRIPED BASS AT POWER PLANTS ON THE HUDSON RIVER

	MONTHS OF GREATEST IMPINGEMENT			MONTHS OF LEAST IMPINGEMENT		
POWER PLANT	1973	1974	1975	1973	1974	1975
Bowline Point	1,2,4,12	1-3	1,3,4,12	6,8-10	6-9	6,8-11
Lovett	4,8,11,12	1,2,4	1-4	1,5,7,10	5,7-9	5,7,8,10
Indian Point 1		1,3,4,12			6-9	
Indian Point 2	1,3,4,12	1-3,5	2-4,7,8	5,7,9,10	6,7,9-11	3,5,6,11
Roseton		5,6,10,11			1-4	
Danskammer 1 and 2	9-12	6-9		1-4	1-3,5	
Danskammer 3 and 4	9-12	6-9		1,3-5	2-4,11	
Albany		6-9			1-3,12	

Source: Appendix E, Table 5.5-3.

all of these species may be related to the migratory and seasonal behavior aspects of their life histories.

4.185 The temporal pattern of striped bass impingement at power plants along the Hudson River varied between the upstream stations and those farther downstream (Tables 4-35 and 4-36). For Bowline Point, Lovett, and Indian Point, impingement rates tended to be greatest during the winter and early spring (December through April) and least during May through October. At Roseton, Danskammer, and Albany impingement tended to be greatest from June through October or November and least from January through April. The reason for this pattern is not clear. One possibility is that downriver plants are impinging young-of-the-year striped bass during their first winter, while upriver plants are impinging yearling striped bass.

4.186 Information relating numbers of fish impinged must be assessed relative to the total population size, natural mortality rates, reproduction capability, and life history biology of a species to determine the significance of the impact from impingement. Conditional impingement mortality may be used as an initial measure of impingement impact on a population of fish. Conditional impingement mortality is defined as the fraction of a population killed due to impingement and is most accurately applied on a species year-class cohort basis. The usefulness of this measure is that it estimates the impingement-related fractional reduction in year class abundance in the absence of other sources of mortality and compensation. Estimates of conditional mortality vary depending on assumptions made in developing input data and scenarios (Barnthouse, 1979).

Cumulative Long-Term Impacts to Adult Fish Populations of the Hudson River

4.187 Mortality of fish eggs, larvae, and juveniles due to entrainment and impingement at power plants on the Hudson River (presented in previous sections) represents an immediate impact to each new year class of fish. As discussed, estimates of these parameters can be made with a fair degree of confidence based on available technology and procedures. At the heart of the dispute over the need for cooling towers at Bowline Point, Roseton, and Indian Point generating stations, however, is the long-term effect of the impact of entrainment and impingement mortality on the abundance of adult fish in the Hudson River. Estimation of the reduction in future adult population levels is difficult because of reasons related both to the present state of knowledge of fishery population dynamics, data required to test and apply present theories of fishery management, and problems with the adequacy of data presently available on fish stocks of the Hudson River.

4.188 At present, the Utilities have utilized two methods of estimating long-term impacts, both based on an extension of a current theory of population dynamics. The U.S. Environmental Protection Agency has criticized the underlying data and theory of the Utilities' presentation and has taken the position that the long-term impact on adult populations cannot be predicted from data presently available from the Hudson River and that theory and methods are unlikely to be developed in the near future that would allow accurate estimation of the impacts of entrainment and impingement mortality on adult populations.

Estimates by the Utilities of Long-Term Impacts to Fish Populations

4.189 The Utilities have used the Equilibrium Reduction Equation method and the Real-Time Life-Cycle Model as their two methods for predicting long-term impacts to adult fish populations (McFadden, 1977; McFadden and Lawler, 1977). The Equilibrium Reduction Equation method consists of entering mortality statistics reflecting power plant operation into an equation that predicts the percentage by which the particular fish population would be reduced on the average in the long term. Inputs to the equation are derived from data for a particular year. The prediction of long-term impact that is calculated represents the impact that would be expected if those same conditions occured every year in the future. The Equilibrium Reduction Equation cannot be used to predict the consequences of future changes in power plant operational conditions or the start-up of new power plants. Impact estimates for striped bass, white perch, Atlantic tomcod, and American shad have been made using this calculation.

4.190 The Real-Time Life-Cycle Model is a computer simulation that has been used in conjunction with the Equilibrium Reduction Equation to predict impacts resulting from plant operational patterns that vary from year to year and from new plants that are expected to commence operation in the future. To date, only estimates of impacts on striped bass are available from the use of this simulation.

4.191 The Utilities have based their impact estimates on data gathered from the Hudson River and on several theoretical considerations. These considerations are as follows:

- That the process of compensation is operating within the affected fish populations of the Hudson River.
- That an inverse relationship between growth rate and abundance of juvenile striped bass can be demonstrated as evidence of the existence of compensation.

- That hypotheses of natural population regulation concerning the relationship between the numbers of spawning adults and the numbers of offspring ultimately entering the fishery (stock-recruitment models) can be applied to fish species of the Hudson River as a way of estimating their compensatory response to additional mortality resulting from entrainment and impingement.

- That the Ricker model of stock recruitment is most appropriate for Hudson River fish species.

- That data from the Hudson River are adequate to estimate the parameters of the Ricker formulation, which is the basis for all estimates of long-term impact.

- That a value of 4 for the parameter α (used as an index of the magnitude of compensation) in the Ricker equation is a conservative estimate for application to the Hudson River situation.

These premises are discussed in turn below.

4.192 Demonstration of Compensation in Fish Populations. An important base on which the impact estimates of the Utilities rests is the degree to which compensatory mechanisms exist within the dynamics of the fish populations in the Hudson River. The existence of such mechanisms would tend to offset the effects of any additional mortality resulting from power plant operations. Compensation refers to the tendency of populations of living organisms to experience an increase in death rate or decrease in birth rate as the number of organisms increases. Conversely, compensation also requires a decrease in death rate or increase in birth rate as population size declines (McFadden, 1977). A number of mechanisms could be responsible for this effect. These include changes in competition for resources, predation, or cannibalism (McFadden, 1977). The position of the Utilities is that empirical demonstration of compensation acting in fish populations is well documented in the scientific literature and that compensatory mechanisms may act rather strongly to offset increased mortality from power plants (McFadden, 1977). In general, the controversy over compensation has not involved its existence but rather how strongly it operates in fish populations.

4.193 The most recent data to demonstrate compensation operating in the striped bass and white perch populations in the Hudson River have been presented in Utility Exhibits 49 and 50 (undated) submitted as part of the Utilities' case in the Adjudicatory hearings of Environmental Protection Agency. In both of these investigations, the negative correlation found between population size and growth rate of juveniles was presented as evidence for the operation of compensation that is, growth rate is not constant but is affected by the number of juvenile fish percent during any year.

4.194 In Utility Exhibit 50, an index of young-of-the-year population size striped bass and white perch was obtained by averaging catch-per-unit effort values for day bottom trawls at three river stations near the Bowline Point generating station for September, October and November. The index of population size was the grand average for the three monthly means. The index of growth was the mean total length attained by a random sample of young-of-the-year fish collected from 1971 through 1976 by beach seine and bottom trawl from the Bowline Point vicinity at or near the end of the growing season (October for striped bass, November for white perch). This index of growth was negatively related to the natural logarithm of fall population size when variations in river flow for February through August were held constant (flow index).

4.195 In Utility Exhibit 49, riverwide data were used to estimate population and growth of young striped bass. When the effects of water temperature on growth were taken into account, a significant inverse relationship between fish population size and growth rate was found during July and August for 1965 through 1976.

4.196 <u>Justification for Using Stock-Recruitment Theory and the Ricker Formulation</u>. Given that the process of compensation can be demonstrated as occuring within some fish species in the Hudson River, the Utilities feel that a proposed theory of natural population regulation that is concerned with the relationship among the size of an adult fish population (spawners) and the size of the offspring population (recruits) at some specified age (often the age at which they become vulnerable to capture by the commercial fishery) can be applied with confidence as the basis for the estimation of long-term impact to the fish stock (McFadden, 1977). These theories have been called spawner-recruit or stock-recruitment models of population dynamics. Among the various theories that have been mathematically defined, the Utilities feel that the formulation proposed by Ricker (1954) best describes the dynamics of the fish species effected by power plant operation in the Hudson River because the Ricker formulation emphasizes the compensatory nature of the numerical relationship between parent fish and the progeny they produce and the importance of the earlier life history stages in compensation (McFadden, 1977, section 10.3). Because the original Ricker formulation applies to a single age spawning population, the Utilities have developed an extension of the theory for use with multiple age spawning populations such as striped bass. The finding of that analysis was that the original formulation provided a conservative estimate of power plant impact (McFadden and Lawler, 1977).

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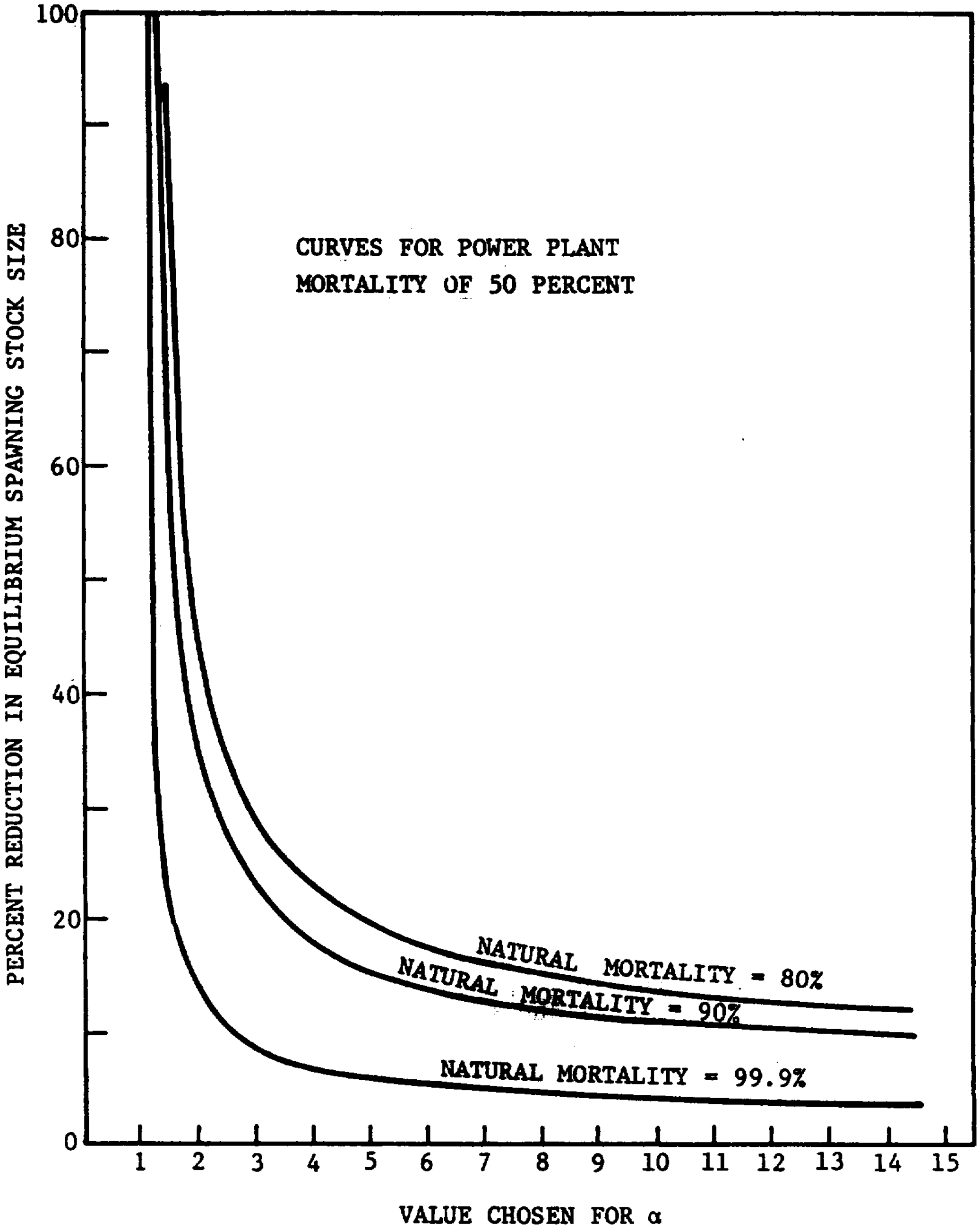
4.197 Evaluation of the parameter α in the Ricker Formula. An aspect of the Ricker formulation that is very important to the estimate of the magnitude of power plant impacts on adult fish populations is the value of the parameter α (alpha), which can be used as an index of the amount of compensation in a particular species. The value of α can be estimated by fitting the Ricker formula to a plot of a time series of data of adult population size (adult stock) versus the resulting progeny population size (recruits). Catch-per-unit-effort data for the commercial striped bass fishery on the Hudson River have been used to estimate the size of the adult stock and corresponding progeny with various lag times between parent and progeny generations used in the analysis. The most recent analysis is given in Utility Exhibit 58. In this analysis, values of from 2.7 to 5.3 were calculated for striped bass. These calculations were considered by the utilities to support the previous utilities contention that an α value of 4.0 used in impact estimates is a conservative value (McFadden, 1977; McFadden and Lawler, 1977). The value of 4.0 for α is a particularly important aspect of the Utility impact analysis because the estimate of long-term reduction in the adult population of striped bass using the Utilities' method increases very rapidly with values of α smaller than 4.0, as shown in Figure 4-9.

4.198 The Real-Time Life Cycle Model. The Real-Time-Life-Cycle Model is a computer simulation that has been used by the Utilities to predict long-term impacts to striped bass under changing environmental and power plant operational conditions (McFadden and Lawler, 1977). The model utilizes a simulation of the hydrodynamics of the Hudson River estuary to determine distribution of striped bass eggs and larvae and a life cycle model to predict the long-term reduction in the size of the adult population. Details of the model are given in McFadden and Lawler (1977).

4.199 In the young-of-the-year portion of the Real-Time Life-Cycle Model, both vertical and longitudinal migration rates are calculated directly from field data on distribution of eggs and larvae. These migration rates are combined with total egg production, mortality rates, entrainment and impingement rates, and river transport processes to generate standing crop estimates throughout the year. Recruits to adult age-group 1 (one-year-olds) are derived from the number of juvenile fish remaining on day 365 after first spawn. The number of recruits, together with density-independent survival rates, is then used to generate an adult population for age groups 2 through 14. Given this total adult population, the percentage of females in it, and the average fecundity and maturation within each age group, the total number of eggs that will be produced by the population is predicted; this total then serves as an input to the young-of-the-year model to generate a new group of one-year-olds, and so on.



Source: McFadden, 1977.

FIGURE 4-9
EFFECT OF PARAMETER α FROM THE RICKER STOCK-RECRUITMENT RELATIONSHIP ON ESTIMATES OF PERCENT REDUCTION IN EQUILIBRIUM SPAWNING STOCK OF STRIPED BASS

4.200 Data requirements of the model are parameters related to river geometry and mass transport, biological factors, and power plant operation. In the river transport model there are 29 longitudinal segments divided into 2 vertical segments of equal depth. In addition, a correlation was developed between the 12 sampling regions of the field surveys of the distribution of eggs and larvae and the 29 segments of the model, so as to permit direct input of field estimates of egg production and comparison of output with Texas Instruments estimates of standing crops for later life stages.

4.201 The simulation of the hydrodynamics of tidal action in different layers of the river requires estimates of the maximum flows in the upper and lower layers during the ebb and flood tides as well as net flows. These flows were obtained and/or calculated from various field surveys, from modeling studies which employ a three dimensional model of the Hudson and, in particular, from 1974 and 1975 flow data.

4.202 Biological parameters include egg production, natural mortality rates and duration of life stages, compensation parameters, larval and juvenile migration, and adult survival and reproduction parameters. Temporal and spatial distribution of eggs, larvae and juveniles as measured during 1974 and 1975 were used to calibrate the model. The compensation function is based on the Beverton-Holt formulation and is calibrated through the Ricker stock-recruitment analysis for an alpha value of 4.0.

4.203 Parameters related to power plant operation include plant location, plant flow rates, impingement rates, and factors related to entrainment. The entrainment factors include the portion of the water mass subject to entrainment, the percentage of organisms in the river that are drawn through each power plant, the fraction of entrained organisms that survive, and the percentage of entrained water that is recirculated.

4.204 Year-to-year variation in environmental and biological factors has been provided for in the model through random variation in freshwater flow, the temporal and spatial distribution of striped bass spawning, and the percentage of organisms in the river that are drawn through each plant. Random sequences of conditions used are based on historical data.

4.205 Estimates by the Utilities of Long-Term Reduction in Fish Stocks. Estimates by the utilities of the long-term reduction in the size of the adult fish stocks in the Hudson River have been made using the Equilibrium Reduction Equation only for striped bass, white perch, Atlantic tomcod, and American shad for 1974 and 1975 (Table 4-37). The impacts of the Danskammer and Lovett Plants are

TABLE 4-37

UTILITY ESTIMATES OF LONG-TERM REDUCTION IN SOME ADULT FISH STOCKS AS ESTIMATED WITH THE EQUILIBRIUM REDUCTION EQUATION

POWER PLANT	PERCENT REDUCTION IN EQUILIBRIUM LEVEL OF ADULT STOCK RESULTING FROM: ENTRAINMENT LOSSES 1974	ENTRAINMENT LOSSES 1975	IMPINGEMENT LOSSES 1974	IMPINGEMENT LOSSES 1975	COMBINED LOSSES 1974	COMBINED LOSSES 1975
			STRIPED BASS[d]			
Bowline[a]	1.9	2.2	2.5	0.6	4.4	2.8
Roseton[b]	NE	2.6	NE	<0.1	NE	2.6
Indian Point[c]	4.2	4.4	0.6	1.0	4.8	5.4
Combined	6.1	9.2	3.1	1.6	9.2	10.8
			WHITE PERCH[e]			
Bowline[a]	1.6	1.3	2.2	NE	3.8	NE
Roseton[b]	NE	1.5	0.2	NE	0.2	NE
Indian Point[c]	2.9	2.4	7.1	NE	10.0	NE
Combined	4.5	5.2	9.5	NE	14.0	NE
			ATLANTIC TOMCOD[f]			
Bowline[a]	NE	2.1	<0.1	NE	NE	NE
Roseton[b]	NE	<0.1	<0.1	NE	NE	NE
Indian Point[c]	NE	0.5	1.0	NE	NE	NE
Combined	NE	2.7	1.0	NE	NE	NE
			AMERICAN SHAD[g]			
Bowline[a]	0.6	NE	0.8	NE	1.4	NE
Roseton[b]	NE	NE	0.1	NE	0.1	NE
Indian Point[c]	1.7	NE	0.8	NE	2.5	NE
Combined	2.3	NE	1.7	NE	4.0	NE

[a] Unit 2 activated May 1974

[b] Unit 2 activated September 1974, Unit 1 activated in December 1974

[c] Includes small effect from Unit 3 in some estimates

[d] $\alpha = 4.0$ [e] $\alpha = 3.5$ [f] $\alpha = 4.5$ [g] $\alpha = 2.0$

NE = not estimated

Note: date in column heading is year class

Source: McFadden and Lawler, 1977.

not included in the calculation since the utilities believe that they have been operating long enough to have their effect reflected in the baseline condition. As discussed above, a value of $\alpha = 4$ was used for striped bass. Values of α for the other species were not determined empirically, but were chosen from among curves presented in Ricker (1975), based on what is known about related species (McFadden and Lawler, 1977). If the same power plant and natural ecological conditions actually occurring during 1974 and 1975 were to continue through the operating lives of the plants, the utilities estimated that the fish populations would be reduced by the given percentages below the average level that characterized the stock before the new power generating units were activitated.

4.206 The predicted reduction in the striped bass population was in the range of 9 to 11 percent (Table 4-37). For the two years, the main impact was due to entrainment losses with about one-half of the entrainment impact occurring at the Indian Point generating station. Impingement impact was variable among plants for the two years.

4.207 Reduction in the white perch population was estimated to be 14 percent based on 1974 data. Impingement losses were of greater magnitude than entrainment losses. The greatest effect of impingement was due to the Indian Point station.

4.208 Limited data are available for Atlantic tomcod. Stock reduction due to entrainment conditions prevailing in 1975 was estimated to be 2.7 percent, most of which was due to the Bowline Point plant. Reductions due to impingement in 1974 was estimated to be 1.0 percent, almost all of which was due to the Indian Point plant.

4.209 Simulation of 40 years of operation of Indian Point units 2 and 3, Roseton units 1 and 2, and Bowline Point units 1 and 2 using the Real-Time Life-Cycle Model gave a predicted 8 percent reduction in the equilibrium level of the adult stock of striped bass (McFadden and Lawler, 1977). Indian Point unit 1 and the Lovett and Danskammer plants were not included in the model run because their impact was believed to be already reflected in the baseline conditions.

4.210 U.S. Environmental Protection Agency Review and Analysis of Utility Estimates of Long-Term Impacts to Adult Fish Populations. The Utilities have used data from the Hudson River and various statistical tests to support and implement the theoretical basis of their analysis of the impacts of power plant operations, as described above. The following data and statistical evaluations are important to the analysis of the utilities.

- Data on abundance and growth of juvenile and young-of-the-year striped bass and white perch are adequate to demonstrate a negative relationship between abundance and growth, thus demonstrating the existence of compensation in these populations.

- The catch-per-unit-effort data from the Hudson River are adequate to estimate the size of the parent stock and recruit resulting recruit population as input to the Ricker stock-recruitment model.

- The Ricker model fits the spawner-recruit data with satisfactory statistical significance.

- Statistical analyses of data from the Hudson River indicate that a value of $\alpha = 4$ is conservative for striped bass and that values for other species can be estimated adequately.

4.211 The U.S Environmental Protection Agency (EPA) and their consultants have evaluated the Utility analyses in testimony dated April and May, 1977. In general, the EPA has determined that:

- The demonstration of a negative correlation between juvenile population size and growth does not hold up when the statistical basis of the analysis is examined and data for 1977 are added to the analysis

- The questionable accuracy of the catch record gathered by the National Marine Fisheries Service and the estimate of fishing effort calculated by the Utilities make the reliability of these data insufficient for use in determining adult spawning and resulting progeny population sizes

- There is no valid basis for selecting the Ricker model over other models of population dynamics (such as the Beverton-Holt formulation) that could also apply to the fish species of the Hudson River

- The fit of the Ricker model to the spawner-recruit data from the Hudson River is poor and is no better than the fit to random numbers

- Because of the above considerations, the Utility estimates of the parameter α derived from the fitting of the Ricker curve to the spawner-recruit data are unreliable

- Because it is an unreliable estimate, the value of α for striped bass could be much lower than the value of $\alpha = 4$

estimated by the Utility, which would result in a much larger estimate of long-term reduction in the equilibrium level of the adult striped bass population than the Utilities' estimate of 8 to 10 percent.

Each of these findings is discussed in more detail below.

4.212 Analysis of the Utilities' Demonstration of Compensation. The Utilities' demonstration of an empirical relationship between population size and growth of juvenile and young-of-the-year striped bass and white perch has been presented in Utility Exhibits 49 and 50. In Utility Exhibit 49, riverwide beach seine data for juvenile striped bass were utilized to estimate population size and growth. The effects of variations in growth rate due to water temperature were accounted for by including the rate of Hudson River temperature increase from 16 to 20 C as a variable in these regressions. A statistically significant negative correlation was found between population size and incremental growth and relative growth of juvenile striped bass when the effects of temperature were held constant.

4.213 In Utility Exhibit 50, an index of young-of-the-year population size (year class strength) was obtained by averaging catch per unit effort values for daytime bottom trawls taken from September through November at three stations in Haverstraw Bay near the Bowline Generating Station. The logarithm of population size rather than population itself was used as an index of fish abundance. The analysis in Utility Exhibit 50 took variations in river flow between February and August into account as a variable affecting growth, as opposed to the analysis in Utility Exhibit 49, in which the effects of temperature on growth were factored out. Statistically significant negative relationships between length and the logarithm of population size, once variations in river flow were accounted for, were found for striped bass and white perch for the years 1971 through 1976.

4.214 Examination of the Utilities' demonstration of an empirical relationship between population size and growth of young-of-the-year and juvenile striped bass and white perch has been presented in Barnthouse (1979), Rohlf (1979), and Fletcher and Deriso (1979). In general, these authors express serious reservations about the quality of the data on fish population size and growth and on the statistical analyses used to infer the negative relationship between population size and growth.

4.215 Barnthouse (1979) and Rohlf (1979) have reanalyzed the data in Utility Exhibit 50 by including data for 1977. In both cases, the significant relationship between growth and population size for striped bass disappears when the datum point for 1977 is added to the regression analysis. However, a significant negative correlation was still obtained for white perch.

4.216 Fletcher and Deriso (1979) believe that the measure of abundance for striped bass (based on data from September through November) is not appropriate, since the length of striped bass from October samples were used as indexes of growth. They feel that data for November would be irrelevant to a measure of growth based on data for October and that the analysis should be based on abundance data only from samples obtained prior to November.

4.217 Rohlf (1979) has questioned the use of the type of index of river flow chosen for use in Utility Exhibit 50 (seven month period principal component score), stating that such an approach has no clear biological basis. He feels that total flow during the growing season or a weighted average flow based on some demonstrated biological importance of flow during different months would be a more reasonable way of including the effects of river flow in the analysis.

4.218 Pooling of data may have also affected the results obtained. Data for the years 1974 through 1976 used on the analysis in Utility Exhibit 50 were from samples that had been pooled for all stations and types of collection gear. Barthouse (1979) has noted that this pooling would not introduce bias into the analysis if the average lengths of fish collected with each gear type were the same or if the distribution of the total catch among the various gears were the same from year to year. Since these conditions were not met, it is as equally possible that errors introduced by the pooling procedure obscured the true relationship between population size and growth as it is that the errors introduced a spurious correlation and that in reality no relationship between population size, growth, and river flow exists.

4.219 Barnthouse (1979) and Rohlf (1979) have also pointed out problems in the analysis of the relationship between population size and growth presented in Utility Exhibit 49. Because the beach seine data for striped bass for 1969 through 1972 were only for the Indian Point area, these data have been converted, using riverwide data for 1973 through 1975, to be equivalent to riverwide samples. There is so much variation in the technique used to adjust the data, however, that Barnthouse (1979) feels that little confidence can be placed in the derivation of the adjustment factor. As a result, the adjusted population levels determined for 1969 through 1972 could be as much as from one-half to twice the value estimated for each of these years. Excluding these years and recalculating the regression analysis given in the Exhibit results in no statistical relationship between population size and growth.

4.220 The datum point for 1969 has been found to be particularly important to the analysis in Utility Exhibit 49 (Barnthouse, 1979; Rohlf, 1979). Data for that year were from the Indian Point region only. The sampling effort was also unusually low. Analysis of residuals (a statistical method of assessing the relative importance of the datum point for each year in determining the fit to the multiple regression model) indicated that the datum point for 1969 has a disproportionally high contribution to the fit of the regression model compared to other points (Rohlf, 1979). When the 1969 datum point is excluded and the multiple regression recalculated, no statistically significant correlation between population size and growth is obtained (Barnthouse, 1979).

4.221 Barnthouse (1979) and Rohlf (1979) have compared the analyses presented in Utility Exhibits 49 and 50, because one analysis considered temperature but not river flow and the other considered river flow but not temperature as the important environmental variable to be accounted for in the regression analysis. Since both analyses are examining the same population, the growth and abundance indices determined in both analyses should be positively correlated with each other. As calculated in Barnthouse (1979), the correlation of the incremental and relative growth indices of Utility Exhibit 49 to the growth index used in Utility Exhibit 50 was not statistically significantly different from zero for striped bass. The correlation of striped bass population size was zero or negative. Similar comparisons of the white perch analyses found no correlation between population size indices. One comparison of growth indices did give a significant positive correlation. Barnthouse (1979) feels that a finding of strong positive correlations between the sets of growth and abundance indices developed in the two Exhibits would have provided strong support for the results and conclusions presented. He feels that the general absence of such correlations casts serious doubt on the validity of the analyses in both Exhibits.

4.222 Rohlf (1979) noted the inconsistency in the conclusions of Utility Exhibits 49 and 50 because different factors affecting growth were used in each. The analysis in Utility Exhibit 49 used population size and water temperature as predictors in the regression analysis of the effects on growth, while the analysis carried out in Utility Exhibit 50 used the logarithm of population size and river flow as predictors. When the regression analysis of data from Utility Exhibit 49 was recalculated using the predictors from Utility Exhibit 50, it was found that the predictors used in Utility Exhibit 50 were poorer predictors of growth rate than the predictors actually used in Utility Exhibit 49. The same conclusions were reached when the predictors from Utility Exhibit 49 were applied to the data in Utility Exhibit 50. The inconsistencies were felt to be a result of the small sample sizes available (Rohlf, 1979).

4.223 Another statistical problem with the analysis in Utility Exhibits 49 and 50 is that the temperature and flow variables used were selected on their observed ability to predict population size using the same set of data. Rohlf (1979) states that this invalidates the probabilities found in all tests of significance, since these tests they are conditional on the preliminary results of the same set of data. Validation of these results using an independent set of data would be necessary.

4.224 Quality of the Catch-per-Unit-Effort Data from the Hudson River. As discussed earlier, the Utility analysis of long-term impact on fish populations is based almost entirely on the use of the Ricker stock-recruitment model. Because the parameters of the Ricker formulation are calculated from the fit of the model to estimates of the population size of adult spawners and their resulting progeny, the quality of the data used to estimate yearly population size in the Hudson River is very important to the analysis. The Utilities have utilized a portion of the commercial catch data from the Hudson River available from the National Marine Fisheries for the years 1931 through 1975 (McFadden, 1977; McFadden and Lawler, 1977; Utility Exhibit 58). These data and an independent measure of the fishing effort expended in landing the catch are used to calculate catch-per-unit-effort as the measure of stock size.

4.225 Fletcher and Deriso (1979) have examined the quality of the available catch-per-unit-effort calculations of the utilities. These authors have noted that the catch statistics are not actual catch data but are estimates by selected fishermen of what they recall their catch of shad and striped bass to be from the year previous to each survey. Since the catch data survey was principally concerned with the shad fishery, the Utilities' analysts used a constant adjustment factor for years prior to 1965 to correct the catch data to reflect the landings of those fishermen whose catches consisted principally of striped bass and, therefore, were not included in the survey. Fletcher and Deriso (1979) have also noted that the data on effort expended in landing the catch are not actual measurements of the effort expended by the fishermen included in the survey but were calculated independently from fishing gear registration records and state laws regulating gear use.

4.226 The uncertainties associated with the catch and effort data have been reviewed in McFadden (1977), Fletcher and Deriso (1979), and Goodyear (1979a). There are seven main sources of error as summarized in Fletcher and Deriso (1979).

- The anecdotal nature of the data collection method is an unreliable indicator of catch.

- The sampling method is inconsistent because of changes in interviewers.

- The fishermen surveyed are not held accountable for the accuracy of their information.

- There were no independent methods of verification of the data.

- The effort figures to be paired with the catch figures are not the efforts actually expended by the fishermen from whom the catch figures were obtained.

- A constant correction factor was applied to the data prior to 1965.

- The assumption of 100 percent use by fishermen of all gear registered in any year and of 100 percent use by every fisherman of the entire statutory fishing season is unrealistic.

4.227 Because of the requirement in the stock recruitment concept for pairing estimates of adult the population size of spawners with those of recruits several years later, the number of data points obtainable from the catch record is fairly small. As a result, the fit of the Ricker curve to the estimates of the size of the adult spawning stock and resulting progeny that are calculated from the catch and effort data is very sensitive to any errors in the few points available. Fletcher and Deriso (1979) state that the sources of error in catch and effort data cited above make the level of reliability of the data insufficient for their use in estimating spawning stock and recruit population size.

4.228 Analysis of the Use of the Spawners-Recruit Concepts as the Basis for Impact Analysis. In the Utilities' analysis, the estimates of spawning stock and resulting progency population size are necessary inputs to the Ricker spawner-recruit model used to estimate the long-term reduction in adult equilibrium population size due to entrainment and impingement mortality at power plants on the Hudson River. The use of the Ricker spawner-recruit model as the basis for the estimate of impacts is justified by the Utilities on the grounds that stock recruitment principles are widely used in fishery management. General documentation is presented in McFadden (1977), and specific examples of spawner-recruit models considered to have been used in management of fish stocks are given in Utility Exhibit 59. Fletcher and Deriso (1979) have reviewed these examples by corresponding with those agencies cited in Utility Exhibit 59 as using spawner-recruit models in their management activities. All replies to these inquiries indicated that, contrary to the claims of the Utilities, spawner-recruit models were not used in the direct management of fish stocks because of the general unreliability of such models. Fletcher and Deriso (1979) also noted that some of the models listed in Utility Exhibit 59 are not even spawner-recruit models.

4.229 Analysis of the Use of the Ricker Spawner-Recruit Relationship for Fish Populations of the Hudson River. In applying the spawner-recruit concept as the basis for impact estimate, the Utilities have chosen the Ricker spawner-recruit model as the particular formulation that describes the dynamics of fish populations in the Hudson River. The Utilities contend that a statistically significant fit of the Ricker curve can be made to the estimates of the size of the adult and resulting progeny populations of striped bass. From the resulting fit of the model to the data, an estimate can be made of the value of the parameter $\underline{\alpha}$, the value of which is important in estimating long-term reduction in the equilibrium level of the adult population. Documentation of the Utilities' analyses are presented in McFadden (1977), McFadden and Lawler (1979), and Utility Exhibit 58.

4.230 The fit of the Ricker model to the spawner and recruit data presented by the Utilities has been examined by several consultants to EPA (Christensen et al., 1979; Goodyear, 1979; Robson, 1979; Rohlf, 1979). The model was found to fit the available data very poorly.

4.231 Rohlf (1979) recalculated the regression fits of the Ricker curve to the data presented in Utility Exhibit 58 and found that the Ricker model fitted the data very poorly, which was in contrast to the findings presented in the Exhibit. The inclusion in the regression of a variable to account for the effects of river flow only slightly improved the fit of the data.

4.232 Robson (1979), after correcting for statistical defects in the Utility analysis found that the Ricker model provided a poor fit to the data using 4, 5, 6, or 7 year differences between the parent and recruit generations. Except for the analysis using a five year difference, these models were not better than, and, in several cases, worse than a model specifying that no relationships exist among recorded yearly catches. Arranged in rank order, the spawner-recruit data were found to be compatible with the assumption that they constitute a random sample from a log-normal distribution.

4.233 Similar results were obtained by Goodyear (1979), who stated that a large part of the observed fluctuations in the catch data used to derive estimates of spawner and recruit population size is probably a result of random factors that affect the reported catch data or the striped bass population itself rather than a result of compensation operating within the population. To test this, he fitted Ricker curves to random sets of spawner-recruit data base on catch statistics for striped bass from the Hudson River used in the Utility analysis. With the exception of the case using a five year time lag between spawners and recruits, results of these curve fittings to random data were similar to those fits obtained in the Utilities' analysis, indicating that the Utilities' analysis is also consistent with the results that would be expected from regression of random data (e.g., no relationship exists between the size of the adult spawning population and the resulting progeny population).

4.234 The potential significance of the regression fitted to a five year difference between spawners and recruits suggested by the findings of Robson (1979) and Goodyear (1979) was also found to be unreliable because this lag is biologically unreasonable for the Hudson River striped bass population. Christensen et al. (1979) have investigated the use of the five-year lag used by the Utilities to pair estimates of spawners with recruits to the more usual generation time approach, which would require longer lag times. The Utility analysis (called the proxy approach) is based on the belief that striped bass older than 5 years old represent, under equilibrium conditions, the contribution to spawning of 5 year olds later in life. The generation time approach holds that the best pairing of spawners and recruits is the lag time closest to the generation time of the population. The generation time is approximately the age by which a given "average" female fish has contributed one-half of her total expected lifetime egg production.

4.235 Christenson et al. (1979) have tested the reliability of the proxy approach against the generation time approach by fitting the Ricker curve to a simulated set of spawner-recruit data in which the generation time is actually 7 years, but for which the appropriate lag using the proxy approach would be 5 years. A value of $\alpha=10$ was specified for the simulated set of $\underline{\alpha}$ data. For all cases tested, the match of the fitted Ricker curve to the known underlying Ricker curve using a seven-year lag to pair spawners and recruits was always better than the match obtained using a five year lag, indicating that the generation time approach is superior to the proxy approach.

4.236 <u>Analysis of the Value of α for the Ricker Curve</u>. Once the Ricker curve has been fitted to the data on spawners and recruits, the value of the parameter $\underline{\alpha}$ can be determined. The value of this parameter is used by the Utilities as an index of the amount of compensation in the fish populations of the Hudson River and is entered into the Equilibrium Reduction Equation to determine the long term reduction in equilibrium population level of fish populations. Determinations by the Utilities of the value of utilizing data from the Hudson River are presented in McFadden (1977), McFadden and Lawler (1977), Utility Exhibit 58, and Utility Exhibit 137 (1978). A value of $\alpha = 4$ has been concluded by the Utilities to be a conservative estimate for the striped bass of the Hudson River. The reliability of this estimate is of critical importance to the impact analysis because values of α less than 4 would result in estimates of population reduction much larger than those calculated using the value of $\alpha = 4$. Use of values of α greater than 4 would not result in impact estimates much less than those predicted using $\alpha = 4$ (see Figure 4- 9).

4.237 The U.S. Environmental Protection Agency and their consultants have evaluated the Utility estimates of α in Christensen et al. (1979), Fletcher and Deriso (1979), Goodyear (1979), and Ricker (1979). In general, these investigators have found that the estimate of $\alpha = 4$ for striped bass is unrealiable and that the value of α could be much less.

4.238 Fletcher and Deriso (1979) and Ricker (1979) have both calculated α values for striped bass of less than 2. Fletcher and Deriso (1979) utilized Utility beach seine data as estimates of recruits. Spawners were estimated from catch data, but the pairing of spawners with recruits was adjusted by two years based on an analysis of the age composition of the catch. A value of $\alpha = 1.32$ was calculated. Use of this value in the equilibrium reduction equation would result in an estimate of reduction of 80 percent in the equilibrium population level of adults. Eliminating a questionable datum point and recalculating, gave an estimate of $\alpha = 1.604$, which would result in an estimate of a 52 percent reduction in the equilibrium level of adults. The two calculations also indicate the large sensitivity of the Utility method to small changes in the value of α when α is small. Ricker (1979), working from the premise of Gulland's Rule (1970, 1971), calculated a value of $\alpha = 1.95$.

4.239 Goodyear (1979) fitted Ricker curves using the Utilities' method to random sets of spawner-recruit data based on catch statistics for striped bass from the Hudson River. Values of α of from 2.74 to 4.28 were calculated from these data fits. Because such a set of random data can result in values of α similar to the Utilities' estimate of $\alpha = 4$, Goodyear states that the parameter estimate by the Utilities is unreliable and should not be used to forecast the long-term reduction in adults resulting from power plant mortality.

4.240 The reliability of the estimate of α has also been examined by Christensen et al. (1979). Their approach, called validation analysis, involves fitting a Ricker curve using the Utilities methods to a simulated spawner-recruit data set for which the underlying value of α is known and comparing the value of α estimated from the fitted curve to the known value. The simulated time series of data utilized in the procedure is based on the salient characteristics of the Hudson River catch data used by the Utilities in their analysis. The rational behind the validation procedure is that if the predetermined value of α could be estimated from the curves fitted to the simulated data using the Utilities' methods, then it could be concluded that the utility curve fitting technique might be a reliable method of parameter estimation. If the values of α estimated from curves fitted to the simulated data sets were very dissimilar to the known true α for the data, then little or no confidence could be placed in the ability of the curve fitting technique to predict the value for real data from the Hudson River. The general conclusion of the study was that the Utilities' curve fitting exercise was inappropriate to the problem and produced misleading results, and thus the estimates of α obtained are unreliable to the point of being useless. The following specific conclusions were reached:

- For low true simulated values of α (1.0 or 1.25) in a simulated set of data, the curve- fitting exercise consistently tended to overestimate the value of α. True values of α of 5 or more were usually under estimated.

- Changes in the estimate of α were unresponsive to changes in the true underlying value of α for the simulated set of data. As the true value of increased over the range of 1.25 to 20, the mean value of the estimated α values increased from about 2 to 3 for a true of 1.25 to about 4 to 6 for a true α of 20. Individual estimated values showed considerable variation.

- Both the proxy approach and the generation time approach of pairing spawners and recruits provided equally poor estimates of α from the simulated data set.

- Adding a variable to the curve fitting procedure to account for the effects of variation in river flow had very little effect on the estimates of the value of α.

4.241 *Analysis of the Real-Time Life-Cycle Model*. The Utilities' Real-Time Life-Cycle Model has been reviewed by Golumbek et al. (1979). The opinion of these authors is that the model is not a reliable tool for making sound fisheries management decisions. The reasons for this opinion are discussed below.

- The conditional entrainment mortality rate for striped bass loss predicted by the model for 1974 and 1975 (data against which model output is validated) is probably underestimated by 23 to 24 percent. This is because the model tends to move yolk-sac and post yolk-sac larvae to regions of the river below the regions containing the power plants. This finding is supported by the poor correlation of distribution of these larval stages as predicted in the model with field data gathered from the Hudson River.

- Because the compensation included in the model cannot be verified with field data (see earlier sections above), the prediction of total mortality is probably an underestimate.

- Contrary to the Utilities' arguments, Golumbek et al. (1979) believe that the effects of the operation of the Lovett and Danskammer plants should be included in this model.

- The predictions of future impacts are not valid because of the uncertainties associated with utilizing the Ricker formulation and an α value of 4.0, as discussed earlier.

- The one-dimensional transport model used in the stochastic modeling of future conditions is invalid.

- The independence among egg production and early life stage survival in the model is inconsistent with other testimony of the Utilities.

- Use of the Beverton-Holt compensation function in the model is inconsistent with the use of the Ricker function elsewhere in the Utilities' analyses.

- Use of variation in the freshwater flow in the model, while keeping life stage durations and early life stage survivals constant, is inconsistent with other Utility analyses that claim these three processes are related in the Hudson River.

- Application of compensation in the model after year-class strength is set is inconsistent with other testimony of the Utilities.

Contribution of Hudson River Striped Bass to the Atlantic Coastal Population

4.242 Recent data gathered by Texas Instruments (1976) has narrowed the range of previous estimates of the contribution of the Hudson River striped bass stock to the Atlantic coastal population. Analysis of these data (Table 4-38) by Texas Instruments personnel indicated that the Chesapeake Bay stock contributed the largest share of the total coastal population between Cape Hatteras, North Carolina and Maine. The proportion of Hudson-spawned fish increased within

TABLE 4-38

PERCENT CONTRIBUTION OF STRIPED BASS FROM THREE SPAWNING RIVER SYSTEMS TO THE ATLANTIC COASTAL POPULATION

COASTAL REGION	SPAWNING STOCK		
	HUDSON RIVER	CHESAPEAKE BAY	ROANOKE RIVER
Atlantic coast north of Cape Hatteras	7-23	66-90	3-11
Western half of Long Island Sound and the New York Bight	15-32	63-84	1-5
Cape May to the New York Bight and Maine to Western Long Island Sound	0-19	68-96	4-13

the western Long Island Sound-New York Bight Region to a maximum of 15 to 32 percent. The Hudson River is the predominant source for sub-legal size striped bass, collected in the Long-Island Sound-New York Bight Region (see Appendix D).

4.243 The data presented in Table 4-38 are discussed in more detail in Barnthouse et al. (1977). The values given are presented as a range because staff of the Oak Ridge National Laboratory felt that not enough information is yet available to evaluate independently the data analysis carried out in by Texas Instruments (1976).

Impacts to Endangered or Threatened Species

4.244 The shortnose sturgeon, an endangered species, and the Atlantic sturgeon, considered threatened, occur in the Hudson River and may be affected by power plant operation. Although five power plants are found along the Hudson River within the spawning range of the Atlantic sturgeon, it appears that very few eggs and juveniles are entrained (Central Hudson Gas and Electric 1977; Orange and Rockland, 1977; Lawler and McFadden, 1977). Available data presented in Table 4-39 indicate that less than 1 percent of Atlantic sturgeon juveniles are presently impinged by Hudson River power plants (total juvenile population estimated at 100,000) (Dovel, 1979). However, it is likely that a higher percentage may be impinged as a result of new units coming on-line at Indian Point. Dovel (1979) estimates that more than 1 percent of the juvenile population may be impinged annually at Indian Point alone. Although many sturgeon impinged at Bowline Point and Roseton are returned to the river alive there may be significant sublethal effects resulting in additional mortality or population reduction. Sturgeon impinged at Indian Point are not returned to the river alive.

4.245 It has been reported by Huff et al. (as cited in Dovel, 1979) that 22 shortnose sturgeon were impinged by Hudson River power plants between 1972 and 1976. However, Dovel has stated that this is likely to be an underestimate. Three of the 22 shortnose sturgeon impinged were longer then 60 cm, demonstrating that mature sturgeon may be eliminated from the population by power plants. Few shortnose sturgeon eggs, larvae, and juveniles are entrained by the Hudson River power plants under consideration in this document.

4.246 Both species of sturgeon found in the Hudson River have been negatively affected by human activities that have involved alteration of spawning/brooding habitats, degradation of water quality, and overfishing. This has resulted in severe reductions below historical population levels. Sturgeon populations are especially susceptible to mortality because an individual must survive for up to 12 to 18 years before any reproduction is possible. Hudson River

TABLE 4-39

ATLANTIC STURGEON IMPINGED ON INTAKE SCREENS AT HUDSON RIVER POWER PLANTS

YEAR	POWER PLANT									TOTAL
	BOWLINE POINT		LOVETT		INDIAN POINT	ROSETON		DANSKAMMER POINT		
	CAUGHT IN SAMPLES[a]	ESTIMATED TOTALS[b]	CAUGHT IN SAMPLES[a]	ESTIMATED TOTALS[b]	CAUGHT IN SAMPLES[a]	CAUGHT IN SAMPLES[a]	ESTIMATED TOTALS[b]	CAUGHT IN SAMPLES[a]	ESTIMATED TOTALS[b]	
1972	-	-	-	-	35[d]	-	-	-	-	111[e]
1973	14	127	8	107	48	3	11	7	84	377
1974	6	43	9	75	135	4	14	5	53	320
1975	18	115	3	21	123	9	80	1	9	348
1976	5	26	1	6	17	2	15	1	9	73
1977	3	11	0	0	197	11	59	6	35	302
1978	4	-	-	-	-	1[f]	-	-	-	

- Information not available.

[a] Actual count of fish impinged during sampling periods

[b] Consolidated Edison estimated of total impinged sturgeon, obtained from extrapolation of total sample water volumes.

[c] Sum of actual count at Indian Point and estimated total numbers at other plants unless otherwise noted.

[d] Does not include any Atlantic sturgeon impinged before June 1, 1972

[e] From Hoff et al.(1979) as cited in Dovel (1979)

[f] As of 5 June, 1978

Source: Dovel, 1979

power plants now appear to affect only a small number of sturgeon. However, if sturgeon populations begin to recover, as Dovel (1979) maintains is possible, power plant impacts on sturgeon may become more substantial.

IMPACTS ON HUMAN RESOURCES

4.247 The principal function served by the Bowline Point Generating Station and other generating stations on the Hudson River, in relation to the human resources of the study area, is the supply of electrical energy. The station contributes to the area's economy and the welfare of its inhabitants by providing energy to meet the needs of residential consumers, industry, commerce and the public sector.

4.248 As part of the integrated network of the New York Power Pool, the Bowline Point station and the other power plants on the Hudson River estuary are operated to yield the highest degree of reliability and economy in the supply of electrical energy. Contractual agreements among member companies of the pool provide for coordination in the participants' electric systems and a sharing in the benefits that can be realized through such coordination. Electrical energy in bulk is transmitted routinely into, through, and out of the study area (New York Power Pool, 1976).* The benefits associated with electrical energy generated within the area, therefore, may be distributed well beyond its boundaries and, conversely, the area's residents could derive benefits from electrical energy generated in power plants located outside of the area.

4.249 The adverse impacts resulting from the construction and operation of power plants, on the other hand, tend to be more localized. Notable exceptions are such phenomena as the widespread transport of pollutants and the propagation of ecological effects, the implications of which may be far reaching. With these exceptions, it appears that the environmental costs of generating electrical energy are borne disproportionately by a segment of the population generally smaller than the segment deriving the associated benefits.

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*Full economic integration in the day-to-day operations of the New York Power Pool was realized in 1977. Energy to meet the needs of all customers of the member companies is generated in the most economical manner, and account is taken of the efficiency of the generating units within the system, the cost of fuels, and the availability of individual units as well as transmission, reliability and other technical constraints.

4.250 The notion of arriving at an equitable distribution of benefits and costs has attracted considerable attention, particularly in the case of power plants on the Hudson River estuary (for example, Mid-Hudson Patterns for Progress, 1976). The question of equity is recognized here as an important element in gauging the socioeconomic impacts associated with the operation of the Bowline Point Generating Station and other plants on the Hudson River. The related issues, hwoever, are controversial and remain largely unresolved. Accordingly, the approach followed in the present analysis focuses on the socioeconomic effects that are evident and potential effects that may be anticipated from the continued operation of the Bowline Point and Roseton stations. No attempt is made to subdivide the study area or to consider whether the study area as a whole is a net importer or exporter of electrical energy.

Visual Impacts

4.251 The Bowline Point Station appears massive against the background of the Villages of Haverstraw and West Haverstraw. Plant structures are extremely conspicuous from many residentail and commercial sections in the vicinity. The central building, stacks and fuel loading facility are particularly dominant features in the view from much of the riverfront and the east bank of the Hudson River.

4.252 In its setting, the Bowline Point Generating Station is a severe visual intrusion. The intensity of the associated impact is attributed mostly to the scale of the plant structures and the sensitivity of the affected area. Concealment of the plant is virtually impossible due to the local terrain, and the height and starkness of the structures generally compound the effect of bulk. Although the plant is sited in an industrial zone, it is distinguishable from neighboring residential developments and the scenic shoreline of the Hudson River. In addition, a negative value is generally ascribed to large functional buildings where they dominate the visual elements of their immediate environs.

4.253 Reservations concerning the architectural merits of the power plant structures have been expressed by the Hudson River Valley Planning Commission. Despite such shortcomings, however, the Bowline Point station presents the functional aspect of a modern, oil-fired power plant. Equipment, piping and cables are, to a large extent, enclosed or buried. An earthen berm surrounding the fuel oil storage area provides partial concealment of the tanks and related equipment. The exterior color of the main buildings and other major components of the plant have been selected to reduce the visibility of the structures. The plant area has generally benefited from the site preparation work involving the removal of discarded automobiles and other trash, improved drainage and vegetation and pest control measures. Landscaping, particularly in the area of the Bowline Point recreational facility, is adequate.

4.254 Certain factors tend to mitigate the visual impact of the Bowline Point station. These stem from the long history of development on the Hudson River and the numerous visible signs of industrial activity along its shores. Manufacturing plants, quarries, fuel storage facilities, and transportation terminals are commonplace. Major electrical generating facilities sited upstream of Bowline Point include the Lovett Generating Station, in operation since 1949; the Indian Point Station, where construction of the first unit began in 1956; and the Danskammer Generating Station, in operation since 1951. The Bowline Point Station is not a unique installation along the reach of the Hudson River between the Tappan Zee and Mid-Hudson Bridges, but, together with the Roseton and the later units at Indian Point, represent successive additions of relatively familiar features in the visual setting. To a limited extent, the incongruity of the Bowline Point Station at its present location is diminished by the presence of similar facilities within the area.

4.255 The visual dominance of the Bowline Point Station will be aggravated by the installation of a closed-cycle cooling system at the station. An artist's impression, shown in Figure 4-10 illustrates the effect of adding massive natural draft cooling+towers, tentatively identified by Orange and Rockland as the preferred closed-cycle cooling alternative. The towers would be 393 feet in height, 315 feet in base diameter (Orange and Rockland, 1977). Visible plumes from the towers, expected to occur frequently during operation, could add moderately to the visual intrusion (U.S. Nuclear Regulatory Commission, 1976). Cooling systems with mechanically assisted towers might be applied at the Bowline Point station as practical alternatives. These structures are not as high as the equivalent natural draft towers and dimensions are generally more proportionate to the existing structures. Visible plumes generated by mechanical draft towers would remain closer to ground level. An alternative that might prove to be technically feasible (Section 6) is to provide cooling for the station with a single natural draft or mechanical draft tower. This would require a cooling tower with a base area roughly double that of the duel towers discussed above. In the case of natural draft towers, a comminserate increase in height would be needed to generate an adequate flow of air; in the case of a mechanical draft tower, a single tower effectively represents a reconfiguration of the modules or "cells" making up the duel tower system. The potential visual impacts of cooling towers, if these are installed at Indian Point Units 2 and 3, have been studies extensively and are considered by the U.S. Nuclear Regulatory Commission to be

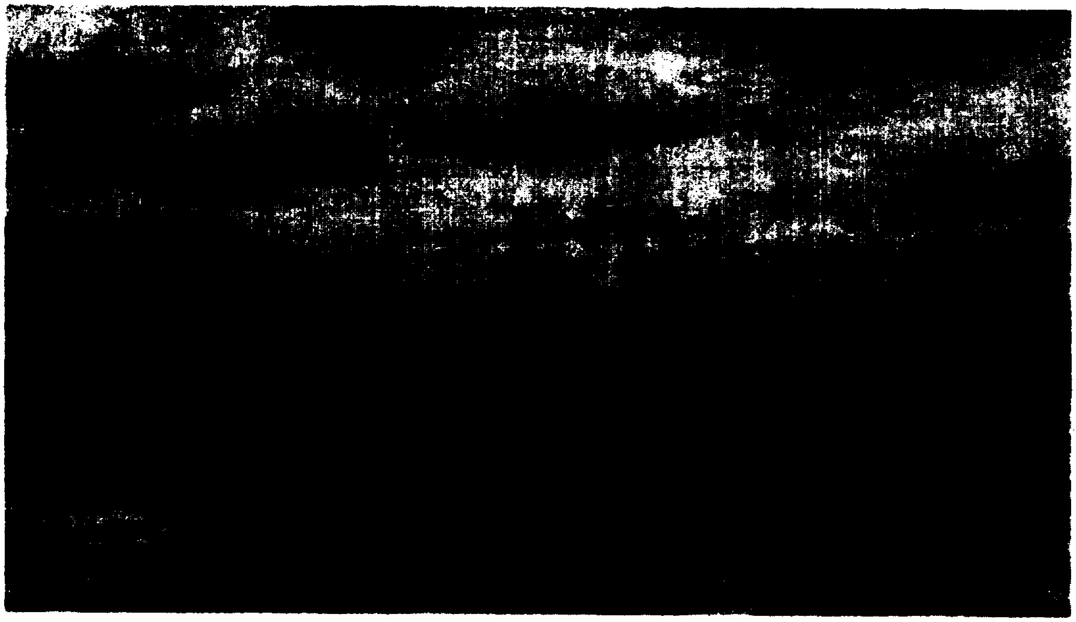

FIGURE 4-10
ARTIST'S IMPRESSION OF THE BOWLINE POINT GENERATING STATION
WITH AND WITHOUT COOLING TOWERS

the "most socially and economically consequential of the various possible environmental impacts" associated with closed-cycle cooling at the Indian Point units (U.S. Nuclear Regulatory Commission, 1976). Considerable opposition to cooling towers at the Indian Point units has been expressed by the Village of Buchanan, the City of Peekskill and others (U.S. Nuclear Regulatory Commission, 1976).

Noise Impacts

4.256 In the initial months of operation, mechanical noise from large fans used at the Bowline Point Station to induce the flow of air and combustion gases through the boiler and stacks, was sufficient to elicit complaints from local residents in the immediate vicinity. Orange and Rockland installed the appropriate silencing equipment and eliminated the source of annoyance. There have been no subsequent complaints concerning noise from the power plant (Rotella, 1977).

4.257 During construction of the cooling towers, noise levels will increase due to fabrication and removal of concrete forms, and the use of cranes, concrete trucks, and excavation equipment. However, the noise will occur only during working hours and will be temporary.

4.258 The level of noise generated by the station may be expected to rise as a result of the operation of a closed-cycle cooling system. Operational noise level in large natural draft towers is generally in the range of 80 to 90 dB(A) (Edmonds et al., 1974). The noise is associated primarily with the falling of water through the towers and the noise generated by the flow of large volumes of air (U.S. Environmental Protection Agency, 1974). Beyond a very short distance from the towers, the sound is "white" or broad spectrum and free of impulses or prominent discrete tone characteristics. During periods of continuous operation, the sound remains constant in level and blends readily in the audible background (U.S. Nuclear Regulatory Commission, 1976).

4.259 Propagation of the sound is affected by many factors, including atmospheric absorption, topography, barriers and vegetative cover. Accordingly, a site-specific study is required to establish the precise sound levels that would be generated by cooling towers serving the Bowline Point station. No analysis of the noise aspect of closed-cycle cooling at the station has been carried out to date (Orange and Rockland, 1976). Drawing a parallel with the natural draft cooling tower proposed for Unit 2 of the Indian Point Station (U.S. Nuclear Regulatory Commission, 1976), it is estimated, for present purposes, that noise increments of the order of 0.5 to 1.5 dB in A-weighted day-night equivalent sound levels (L_{DN}) might be experienced in the residential areas surrounding the Bowline Point station. Increases of this magnitude are considered unlikely to cause reaction from the communities in the vicinity of Indian Point (U.S. Nuclear Regulatory Commission, 1976). The situation may differ somewhat in Haverstraw because of the proximity of neighborhoods to the order of 40 dBA (Orange and Rockland, 1972) characterizing a quiet residential area (New York State Department of Environmental Conservation, 1974).

Public Safety

4.260 The operating plant and storage of fuel oil at the Bowline Point station constitute a finite risk of explosion and fire. However, the likelihood of damage occurring beyond the station boundaries as a result of an accident at the plant is remote. All major equipment installed at the Bowline Point station is of standard design, with a record of safety and reliability established by extensive application in generating stations throughout the country. The plant is operated in accordance with procedures adopted widely by the utility industry. Fire protection systems in the main plant area and fuel storage facility are designed to provide adequate capability to extinguish major fires and prevent their spreading. An interconnection between the two systems ensures added backup capability in the event of a serious emergency (Orange and Rockland, 1971). The associated hazard to public safety is considered to be at a generally acceptable level.

4.261 Fuel oil is delivered to the site by barge or tankers. River traffic to and from the plant is readily accommodated and poses no undue hazard to waterborne commerce or pleasure boating. Occasional deliveries of equipment and materials to the power plant constitute a minor demand on railroad and transportation systems serving the area. The power plant is staffed continuously with three work shifts per day. At times of shift changes, automobile traffic in the vicinity of the plants increases but causes no appreciable congestion or unusual hazard on local roads (Rotella, 1976).

Employment and Local Economy

4.262 The Bowline Point Generating Station provides employment for a work force of 100 persons that includes plant operators, maintenance staff and administrative personnel (Chapter 3). Employees reside in a wide area surrounding the station and commute to work (established during site visit on 3 and 4 November 1976).

4.263 The owners of the Bowline Point station make annual tax payments amounting to approximately $8 million to the Town of Haverstraw and the Village of Haverstraw. Details of these payments are as follows:

YEAR	TOWN OF HAVERSTRAW STATE AND COUNTY	SCHOOL TAX	VILLAGE OF HAVERSTRAW
1975	$2,730,000	$4,700,000	$175,000
1976	$3,028,000	$4,900,000	$176,000
1977	$3,003,000	Not Available	

Information supplied by Orange and Rockland, Utilities, Inc..

4.264 The service requirements of the operating station are readily accommodated by the local infrastructure (Rotella, 1976; 1977). Water is supplied to the station by the municipal system at the rate of 275,000 gallons per day. Approximately 19,000 gallons per day are returned as sanitary and miscellaneous wastes (Chapter 1 and 4) for treatment by the sewage treatment plant. The design capacity of the treatment facility is 4 million gallons per day and is currently adequate (Rotella, 1976; 1977). Small quantities of solid wastes are generated by the operation of the station. Oily wastes and chemical wastes from certain maintenance cleaning procedures (Chapter 4) are disposed of through commercial contractors.

4.265 Construction of cooling towers, if these are installed at the Bowline Point station, is expected to lead to an increase in local traffic and employment. The construction period would extend over two years (Orange and Rockland, December 1974a) and involve an average of 125 workers per year. Orange and Rockland estimates that approximately one-third of the work force would be composed of local residents, the remainder being drawn from the surrounding area. It appears unlikely that the construction work would attract a significant number of people to establish a permanent residence in the vicinity of the power plant. Cooling towers would add an estimated $70 million in capital costs to the value of the station, leading to an increase in local property taxes.

Historical Resources

4.266 On the basis of criteria* developed by the U.S. Department of the Interior to determine the effect of a Federal, Federally-assisted or Federally-licensed undertaking on properties included in or eligible for inclusion in the National Register of Historic Places (39 FR, No. 18), the Bowline Point and other generating stations could have adverse impacts on certain historic properties listed in Table 2-17 by virtue of the visibility of the stations. It is impossible to estimate quantitatively in the severity of these impacts. The Bowline Point station is highly visible and dominant in its setting. Certain factors, discussed above, however, may tend to mitigate the visual effects of the station.

4.267 As discussed earlier in Chapter 4, operation of evaporative closed-cycle cooling systems at the Bowline Point and Roseton generating stations gives rise to the deposition of salt and a remote possibility of generating acidic mists. There is a small attendant risk of causing damage to properties, including those of historic interest in the immediate vicinity of the Bowline Point and Roseton generating stations (Chapter 2). As discussed in detail in Chapter 6, the retrofitting of a closed cycle cooling system at each of these stations would entail a reduction in generating capacity and overall efficiency of the station. In addition to the initial capital cost of the closed-cycle cooling system, there are both economic and energy penalties associated with this loss in efficiency. Further, the operation of an evaporative cooling system would give rise to an increased consumptive use of water, estimated in an earlier part of the present analysis to be of the order of 1.5 to 2 times the current level of consumption.

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*The criteria are:

> "Generally, adverse effects occur under conditions which include but are not limited to:
> (a) Destruction or alteration of all or part of a property;
> (b) Isolation from or alteration of its surrounding environment;
> (c) Introduction of visual, audible, or atmospheric elements that are out of character with the property or alter its setting;
> (d) Transfer or sale of a Federally-owned property without adequate conditions or restrictions regarding preservation, maintenance, or use; and
> (e) Neglect of a property resulting in its deterioration or destruction."

CHAPTER 5
ADVERSE IMPACTS THAT CANNOT BE AVOIDED

5.01 The principal unavoidable impacts associated with the operation of the Bowline Point and Roseton Generating Stations are those occasioned by the physical presence of the power plants (visibility and occupation of land), the release of combustion products and the rejection of waste heat. Both stations are in commercial operation and the unavoidable effects experienced during the construction phase of the projects have completely subsided. There are no indications of tangible, deleterious effects that have persisted from the influx of a large labor force and material, the generation of noise and dust, site clearing, grading, filling, excavation and other activities likely to lead to erosion and turbidity and siltation in nearby surface waters. There are no reasons to believe that the construction of the Bowline Point and Roseton stations has affected groundwaters in their vicinities, or that groundwaters would be affected by the continued operation of these stations.

5.02 Both the Bowline Point and Roseton stations occupy relatively small tracts of land (245 acres and 133 acres, respectively) located at sites previously used by or in the vicinity of brickworks. In relation to the area of the lower Hudson River Valley, the land committed to the Bowline Point, Roseton, and other existing generating stations represents a small loss of wildlife habitat and agricultural and recreational resources. In view of previous uses of land at the Bowline Point and Roseton sites, no areas considered to be prime agricultural lands have been committed. The subject power plants, however, are highly visible from the river and riverfront. While there are no indications that the power plants have depressed property values in their immediate vicinities, the visibility of the stations could act as a deterrent to future developments or redevelopments in the area. Closed-cycle cooling systems at either or both stations would intensify their visual impact, particularly if evaporative natural draft cooling towers are installed.

5.03 Combustion products released by the Bowline Point and Roseton Generating Stations consist mostly of carbon dioxide and water vapor. There are no practical means of containing or controlling the release of carbon dioxide. The observed steady growth in the concentration of carbon dioxide in the atmosphere, attributed principally to the rapidly increasing use of fossil fuels since the turn of the century, is a factor linked closely to a potential inadvertent modification of climate on a global scale (see, for example, Machta and Telegadas, 1974). In this context, the contribution of the Bowline Point and Roseton stations to the carbon dioxide load on the atmosphere must be recognized as an unavoidable effect. No significant localized or regional modifications of the weather, however, are anticipated as a result of the release of carbon dioxide from fossil-fueled power plants on the Hudson River. Similarly, perturbations in temperature and the moisture content of the atmosphere, caused by the release of combustion products and the rejection of waste heat (even through evaporative cooling techniques), are not expected to give rise to any significant meteorological effects (Koenig and Bhumralkar, 1974).

5.04 Together with carbon dioxide and water vapor, the airborne emissions from the Bowline Point and Roseton stations contain measurable quantities of oxides of sulfur and nitrogen and particulates derived mainly from mineral matter present in the fuel oil. Emissions of these substances meet all New York State Standards applicable to stationary combustion installations (6NYCRR227). State ambient air quality standards currently in effect (6 NYCRR 257, effective 18 March 1977) are not being exceeded as a result of the operation of the Bowline Point Station. Central Hudson reports that since 1 August 1976 when the sulfur content of oil burned at the Danskammer power plant was reduced from 2.0 to 1.0 percent by weight, standards related to the concentration of sulfur dioxide are no longer being exceeded in the vicinity of the Roseton station. The Federal secondary standard for ambient concentrations of particulate matter (40 CFR 50.5) is being exceeded occasionally in the vicinity of the Roseton Station. There are no indications of significant interactions of a cumulative nature among the airborne emissions from fossil fueled power stations on the Hudson River estuary. These emissions, nonetheless, contribute to the general level of airborne contaminants in the lower Hudson River Valley.

5.05 Emissions of sulfur and nitrogen compounds will contribute to the overall regional concentrations of sulfate and nitrate aerosols and the attendant hazards of acid precipitation in the northeastern United States (see, for example, U.S. Department of Agriculture, 1976). The interaction of stack gases with atmospheric moisture could, in principle, lead to the formation of acidic mists. This phenomenon could become more prevalent if evaporative cooling systems are installed at the Bowline Point and Roseton generating stations and if the fumes from the stack and cooling systems interact at either station. Experience to date, however, has not shown that such interactions lead to appreciable problems at ground level.

5.06 In addition to the gross contaminants, certain compounds and elements are released in relatively small or trace quantities with the combustion gases. Among these are carbon monoxide, hydrocarbons and aldehydes and a number of trace metals and their derivatives. Trace elements contained in crude oil, other than sulfur and those normally considered to be constituents of mineral matter (silicon, aluminum, iron, titanium, calcium and the alkali metals), include vanadium, nickel, zinc and copper in concentrations that vary, especially with the source of oil (Babcock and Wilcox, 1972). The distillation of crude oil causes virtually all of the metallic compounds and a large part of the sulfur compounds to concentrate in the residue of the process, that is, in residual fuel oil (Babcock and Wilcox, 1972) of the type burned at the Bowline Point and Roseton stations.

5.07 Relatively little is known about the mobilization and ultimate fate of the trace constituents of fuel oil burned in power plants. Recent investigations have dealt with coal fired plants and demonstrated that the disposition of trace elements and compounds is determined largely by their volatility (Natush et al., 1974; Kaakinen et al., 1975; Klein et al., 1975). The most volatile substances probably are discharged in the gaseous phase. Others, including zinc, tend to concentrate in the fly ash discharged from the stack, while the least volatile substances are retained within the boilers. It is unclear at present whether vanadium and nickel exhibit the characteristics of the least volatile substances or whether there is a certain tendency for these substances to escape. Rough parallels may be drawn in the case of fuel oil combustion and it is expected that at least some of the trace constituents of the fuel are released. However, successful efforts at recovering vanadium commercially from slag, bottom ash and boiler deposits at the Albany station and other oil-fueled stations (Electrical World, 1977; O'Neal, 1977; Lalena, 1977) have shown that a substantial portion of the vanadium present in the fuel oil is retained within the combustion system. The behavior of copper is unknown.

5.08 Considerable attention is focused on the trace contaminants from the combustion of fossil fuels because of the carcinogenicity or suspected carcinogenicity of several of the elements and compounds involved (Kornreich, 1976). Accordingly, the release of these substances from the Bowline Point, Roseton and other fossil fueled stations on the Hudson River estuary, is regarded as a contributory risk to public health, presently unavoidable and of unknown severity.

5.09 The withdrawal of water from the Hudson River to provide the means of rejecting waste heat and satisfy other service requirements gives rise to certain unavoidable effects. Under present conditions, the withdrawal of water by power plants on the Hudson River estuary results in the destruction of aquatic organisms by entrainment and impingement. Estimates of the extent of the damage are still the subject of serious scientific debate. Research has been focused principally on the effect that the continued operation of existing power plants with once through cooling would have on the population of striped bass in the Hudson River.

5.10 Present estimates of the Utilities are that the striped bass population would be reduced on the average from 8 to 11 percent with continued operation of existing power plants with once-through cooling systems on the Hudson River. White perch population could be reduced up to 14 percent. Data are not available on possible losses of other species. Staff of the U.S. Environmental Protection Agency believe that estimates are unreliable and that fish population could be affected to a much larger extent. The installation of evaporative closed-cycle cooling systems at all the eligible power plants on the river would reduce but not entirely eliminate the destruction of aquatic organisms. Power plants not subject to the potential requirements to install closed-cycle cooling systems would continue to operate with open-cycle cooling. Moreover, some withdrawal of water would be needed at the power plants with closed-cycle cooling to compensate for operational losses of water. Notwithstanding the unresolved issues, it is evident that some destruction of aquatic organisms is an unavoidable consequence of the operation of the power plants, even with the installation of closed-cycle cooling systems. On the other hand, there is sufficient evidence to suggest that this destruction could be reduced from present levels by means other than cooling towers. In the case of the Bowline Point and Roseton stations, the water intake structures and screening mechanisms could be modified to take advantage of recent developments in techniques aimed at reducing damage to fish as a result of impingement (Chapter 6). A second approach is that of coordinating the operation of power plants on the river and elsewhere in New York State so as to avoid affecting critical areas at critical times (Chapter 6). It is impossible, at present, to predict how successful, if at all, such measures would prove to be.

5.11 Other potential impacts associated with the operation of the Bowline Point and Roseton Generating Stations are minimized through the application of appropriate mitigating measures. The release of waterborne contaminants (except heat) reflects the application of the best available control technology economically achievable, in the context of Section 301 of the Federal Water Pollution Control Act of 1972 (PL 92-500), at both power plants. The attendant impacts on the waters of the Hudson River are small. Small quantities of solid waste, such as ash, spent resins and miscellaneous trash, as well as waste solutions generated by cleaning and other maintenance operations, are disposed of by commercial contractors. Noise from the operating stations is abated by the appropriate suppression equipment to levels sufficiently low to be acceptable to resident communities in the vicinity of the power stations.

5.12 Fuel oil is delivered to both stations by barge or tanker, and added traffic on the Hudson River poses the risk of oil spillage and an additional hazard to commercial and recreational navigation. Both Orange and Rockland and Central Hudson have developed spill prevention control and countermeasure plans (Orange and Rockland, 1974; Central Hudson, 1974) covering these companies' facilities on the Hudson River and incorporating all applicable regulations of the U.S. Coast Guard and U.S. Environmental Protection Agency (40 CFR 112). These plans set forth inspection and operating procedures related to the receiving, storage and transfer of fuel oil and countermeasures and reporting procedures to be followed in the event of spills. The procedures combine regulations and sound engineering practices to ensure that the risk of discharging oil in harmful quantities is minimized.

5.13 Notwithstanding the mitigating measures that have been taken, residual effects and risks persist. In many instances, these could be reduced further through the application of technological controls, procedures and other available measures. The exercise of additional control, however, is presently not considered to be warranted since the health, safety and welfare of the public are not unduly comprimised.

5.14 The use of evaporative closed-cycle cooling introduces a possibility, albeit small, of ground level fogging and icing, air increase in the formation of acidic mists, generation of noise, and deposition of salt (Chapter 6). The phenomenon of drift, which can be reduced to low levels but not entirely eliminated, is responsible for the spread of dissolved and suspended substances contained in the source of cooling water. Damage to vegetation from the deposition of salt is a possibility. Also noteworthy is the presence of polychlorinated biphenyl compounds predominantly in the sediment of the Hudson River. Although the concentration of these substances in solution or suspension may be extremely low, their mobility and high toxicity to humans and other animals are factors that warrant consideration as elements of risk associated with the long-term operation of the power plants with closed-cycle cooling.

CHAPTER 6

ALTERNATIVE ACTIONS

6.01 The District has considered several alternative actions related to its permit authorizing construction in the navigable waters of the Hudson River of water intake structures forming part of the Bowline Point Generating Stations. The alternatives available to the District are to (1) retain unaltered the present permit and related conditions, (2) modify the permit through the imposition of additional conditions, (3) suspend the permit, or (4) revoke the permit.

6.02 Retention of the present permit would allow Orange and Rockland to operate the Bowline Point station without additional regulatory restrictions imposed by the District. Operation could continue throughout the operational life of the plant with the existing once-through cooling system, unless a closed-cycle cooling system is installed at the station in accordance with the current requirements of the U.S. Environmental Protection Agency. Therefore, the District has analyzed the impacts associated with the operation of the Bowline Point station under conditions of both open-cycle and closed-cycle cooling (Section 4). The owners of the Bowline Point station are contesting the need for closed-cycle cooling and adjudicatory hearings on the matter are being held before the U.S. Environmental Protection Agency (Appendix B).

6.03 The imposition of special conditions, in addition to those currently specified in the subject permit, has been considered as the second possible course of action. These conditions could apply to the operation of Bowline Point station with once-through or with a closed-cycle cooling. Suspension of the District's permit, a third possibility would require the Bowline Point station to be shut down until a closed-cycle cooling system is installed. The fourth alternative, revocation of the permit, would cause the permanent abandonment of the plant.

6.04 The same alternatives are available to the District in the case of the permit issued in connection with the Roseton Generating Station. The U.S. Environmental Protection Agency requires that a closed-cycle cooling system be installed at the Roseton station and the owners are contesting this requirement. Accordingly, the District has evaluated the impacts associated with the various alternative actions applied to the Roseton station in the context of continued operation with open-cycle and closed-cycle cooling.

ALTERNATIVE ACTIONS RELATED TO THE BOWLINE POINT STATION

6.05 The current National Pollutant Discharge Elimination System permit governing waterborne discharges from the Bowline Point station requires that operational levels of closed-cycle cooling be attained by 1 July 1981. A final selection of the type of closed-cycle system to be installed at the station, should the requirement for closed cycle cooling remain in effect, has not been made to date. Orange and Rockland has identified evaporative, natural draft cooling towers as the preferred closed-cycle cooling option. A preliminary study (Orange and Rockland, 1974) has demonstrated the engineering feasibility of installing this type of cooling system at the Bowline Point station and established a first estimate of the monetary costs involved.

Retention of Present Permit

6.06 The principal advantages of retaining the present permit stem from the unencumbered operation of the facility and, if a closed-cycle cooling is ultimately installed, an orderly transition from operation with open-cycle to closed-cycle cooling. While operating without additional restrictions, the Bowline Point station would continue to generate electrical energy to meet the needs of customers served by Orange and Rockland, and contribute to the reliability and economy of operation of the New York Power Pool (Appendix C). A closed-cycle cooling system, if retrofitted in accordance with the stipulations of the current National Pollutant Discharge Elimination System permit, would be brought into operation within a period of approximately 4 1/2 years, allowing sufficient time to draw up the detailed specifications and design of the system, secure the necessary authorizations, complete construction and testing and, finally, tie in the cooling system to the rest of the plant. At the time of the Draft Environmental Statement, a preliminary schedule (Orange and Rockland, 1974) showed that construction would proceed over subsequent three years until both towers are completed and equipped with the necessary internal components. Testing and tie-in would extend over two months.

6.07 Retention of the permit implies that the impacts associated with the operation of the Bowline Point station on open-cycle cooling (Chapter 4) would continue to prevail, either for an interim period or until the power plant is retired, depending on the outcome of hearings before the U.S. Environmental Protection Agency. The principal intent of installing closed-cycle cooling at the Bowline Point station is to reduce the rate of intake of cooling water to 2 or 3 percent of that needed for once-through cooling and, thereby, reduce damage caused by entrainment and impingement of striped bass and other aquatic organisms.

6.08 This reduction could be effected by installing one of several alternative closed-cycle cooling systems, each involving a distinctive set of environmental tradeoffs relating to land and water use, the release of water vapor and spray to the atmosphere, the generation of noise, the visual features of the cooling system, and monetary costs. In the analysis of impacts documented so far (Chapter 4), closed-cycle cooling has been treated generically, that is, without consideration of a specific type of cooling system. Exceptions have been made where impacts cannot be assessed without reference to a particular type of system. In such instances, the impacts described are those related to evaporative natural draft towers. The analysis is extended here to consider all of the practical cooling alternatives that might be applied at the Bowline Point station, thereby assessing a range of possible implications associated with the retention of the subject permit.

Cooling Alternatives*

6.09 The once-through or open-cycle technique of rejecting waste heat from an operating steam electric power plant involves a constant withdrawal of cooling water from a suitable source, circulation of the water through the plant condensers and discharge of the heated stream to receiving waters. In a closed-cycle cooling system, heated water from the condenser is passed through a cooling device and is next recycled to the condenser. If cooling is effected to a substantial degree (25 to 75 percent) through evaporation of a portion of the circulating water, the device is said to be evaporative. In such a system, the balance of the waste heat is rejected through the transfer of heat to air. Dry cooling operates entirely on this latter principle. Heat is rejected without any direct contact between air and water, that is, without the assistance of evaporation or the attendant loss of water. Wet-and-dry systems combine the features of evaporative and dry cooling.

6.10 Evaporative cooling systems require a constant supply of water to compensate for evaporative losses, drift (water droplets entrained by the flow of air or wind), and blowdown (a continuous or intermittent purge from the system to avoid an undue buildup of dissolved matter in the cooling water inventory). Although drift

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*A more detailed treatment of the technical characteristics of closed cycle cooling systems is given in Appendix D.

represents the least important component of water consumption, considerable attention is devoted to its associated hazards of depositing salts and other substances potentially harmful to health, vegetation, and property.

6.11 The two broad categories of evaporative cooling systems are cooling ponds and cooling towers. The term cooling pond* designates a manmade impoundment constructed to provide cooling water for steam electric plants or other industrial facilities. The impoundment may take one of several forms, the simplest being a large reservoir that acts as source and sink for a once-through cooling system. Other forms include cooling canals and smaller reservoirs equipped with powered spray devices. Cooling towers are available as natural draft towers, in which the flow of air is induced through the density gradient (temperature and humidity) within the tower, and mechanical draft towers, where the flow of air is either induced or forced mechanically. A number of combinations or hybrid systems represent possibilities that may be advantageous in certain specific applications. These include the wet-and-dry concept mentioned previously and natural draft towers with mechanical assistance. Other cooling systems are designed to reject part of the imposed heat load before a discharge is made to receiving waters. While such systems may be useful where the thermal component of the discharge is an overriding factor, they are not considered further in the present analysis, since the intake rate of cooling water is not reduced by the application of any of these systems.

6.12 The economic penalties of operating a power plant with closed-cycle cooling result from the increase in the temperature of the cooling water at the condenser inlet over temperatures that generally prevail with once-through cooling (Appendix D). There is a corresponding increase in the temperature of the condensate and, consequently, an increase in the back pressure at the steam turbine exhaust. This gives rise to a loss of electrical generating capacity and a decrease in the overall thermal efficiency of the plant. In addition, more energy is expended in circulating the water through a closed-cycle system than is generally the case with once-through cooling. Further losses in electrical output are incurred where power is needed to drive mechanical fans or spray devices.

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*The term "cooling lake" is used occasionally to differentiate an impoundment which impedes the flow of a navigable stream from a "cooling pond" which may draw water from or discharge water to a navigable stream but does not otherwise impede its flow (U.S. Environmental Protection Agency, 1974).

6.13 The principal ecological advantage of the use of closed-cycle cooling over once-through cooling would be to reduce the rate of entrainment and impingement of aquatic organisms (Chapter 4). It may be well to note, however, that the probability of survival of an organism entrainment into a closed-cycle cooling system with cooling towers is reduced practically to zero.

6.14 The principal ecological disadvantage the use of evaporative closed-cycle cooling would be the potential for damage to vegetation from salt drift (Chapter 4). Other disadvantages include the visibility of cooling towers and their plumes as well as the economic and energy penalities associated with these systems.

Closed Cycle Cooling at the Bowline Point Generating Station

6.15 The design specifications underlying the preliminary study of closed-cycle cooling at the Bowline Point Generating Station (Orange and Rockland, 1974) provide the basis for the comparative analysis of cooling alternatives presented here. Each closed-cycle cooling system is sized to reject the current waste heat load and maintain the flow of water through the plant condenser at the current rate. Accordingly, the temperature rise across the condensers would remain unchanged.

6.16 Pertinent design characteristics and conditions applicable to closed-cycle cooling at the Bowline Point station are:

PARAMETER	VALUE
Heat rejection per unit, billion BTU per hour	2.82
Circulating water flow, gallons per minute	375,620
Cooling range, °F	15
Approach, °F	14.9
Design dry bulb temperature, °F	86
Design wet bulb temperature, °F	74

The design temperature of the cooling water at the condenser inlet would increase from the present value of 70 to 89 F., with a corresponding increase in design turbine back pressure from the current 2 inches of mercury absolute to 3 inches of mercury absolute.

6.17 The existing intake structure and service water system would be retained. New pumps would be installed to supply service water at the rate of 8,000 gallons per minute to each of the generating units. Water discharged from the service water system would be made available as makeup for evaporative closed-cycle cooling at a rate essentially equal to that of the intake. It may be well to note that there are design features that apply to the average performance of the system over a given year. Variations can be anticipated throughout the year, with the most efficient operation, of the system expected in cool, dry weather and the least efficient in warm, moist weather. For example, translating the increase in back pressure into a loss of generating capacity, a reduction of the order of 3 percent might be the average for a year's operation but the peak reduction in summer might amount to 5 percent. Further, a design based on these figures is somewhat conservative since the actual heat rejection from each of the Units presently amounts to 2.14 billion BTU per hour (Chapter 1).

Evaporative Natural Draft Cooling Towers

6.18 Rejection of the waste heat load from the Bowline Point Generating Station through evaporative natural draft cooling towers would require two towers, each 393 feet high with a base diameter of 315 feet (Orange and Rockland, 1977).

6.19 Evaporative water losses from each of the cooling towers, estimated on the basis of 0.08 percent of the circulating water rates per degree F of cooling range (Marley, 1969), would average 4,500 gallons per minute (6.5 million gallons per day). Drift losses with standard drift eliminators would amount to 0.05 percent of the circulating water rate or 200 gallons per minute (0.3 million gallons per day). The installation of specially designed drift eliminators could reduce drift to the range of 0.002 to 0.02 percent of the circulating water rate (U.S. Environmental Protection Agency, 1974) and give rise to a corresponding loss in the cooling effectiveness of the tower. With a makeup rate of 8,000 gallons per minute per tower, blowdown could be maintained at an average value of 3,300 gallons per minute or 0.9 percent of the circulating water rate. Under these conditions, the equilibrium concentration of dissolved solids in the cooling water inventory would be a factor of 2.2 higher than the concentration of these substances in the Hudson River. Blowdown taken from the cold side of each tower at the rate of 3,300 gallons per minute and at design conditions of 19 F above ambient river temperature represents a thermal discharge of 31.4 million BTU per hour.

6.20 Other properties of the liquid discharge from the cooling towers and chlorination schedules would have to meet standards characterizing the application of "best available technology economically achievable" (40 CRF 423.13) Among these, the limitations on free available chlorine in the cooling tower blowdown (0.5 milligrams per liter maximum concentration and 0.2 milligrams per liter average daily concentration over 30 consecutive days) make it necessary to install a dechlorination treatment system. In its preliminary investigations, Orange and Rockland has considered a sulfur dioxide chemical feed system to reduce free available chlorine to levels at or below those acceptable to the U.S. Environmental Protection Agency.

6.21 The increased back pressure at the turbine exhaust resulting from the application of evaporative natural draft cooling gives rise to an estimated loss of 6 megawatts of generating capacity per unit at design conditions. Additionally, 3.5 megawatts per unit are needed to meet the increased requirement in power to circulate the cooling water. The total derating of the plant at design conditions amounts to 19 megawatts, representing approximately 1.6 percent of the station's net capability. The total penalty in generating efficiency is 145 BTU per kilowatt-hour, increasing the net plant heat rate from the current value of 9,135 BTU per kilowatt-hour to 9,250 BTU per kilowatt-hour.

6.22 Atmospheric Effects. Theoretical considerations relating to the release of warm, moist air from the cooling towers indicate that a visible plume (or artificial cloud) would be formed under the appropriate meteorological conditions and that a potential exists for creating fog and icing at ground level and causing alterations in local meteorology. Predictive analyses of plume formation by a proposed natural draft tower at the Indian Point site, as well as extensive observations of cooling towers both in the U.S. and abroad (U.S. Nuclear Regulatory Commission, 1976), suggest that plumes from the towers at the Bowline Point station would usually be visible during unit operation. The shape, rise, length, and visibility of the plumes, however, would depend on prevailing meteorological conditions (air temperature, saturation deficit, windspeed and atmospheric stability). The smallest and shortest plumes would occur when the atmosphere is dry (relative humidity less than 85 percent, a condition that is expected to occur with a frequency of 95 percent in the vicinity of Indian Point). The largest and longest plumes would be formed when windspeeds are moderate and the atmosphere is very moist (relative humidity greater than 95 percent, windspeeds between 8 and 18 miles per hour, frequency of occurrence 3 percent). The plumes may then extend for several miles downwind and may merge with low clouds that are often associated with very moist conditions. Strong winds (greater than 19 miles per hour) inhibit the upward development of plumes and, in general, lead to plumes of lesser downwind extent than do moderate winds.

6.23 Because water vapor tends to condense more readily as temperature decreases, cooling tower plumes are most distinct and persistent during the coldest periods of each day and year (U.S. Nuclear Regulatory Commission, 1976). The visibility of a plume can be expected to depend on a number of variables and complex relationships involving the number and density of condensation droplets within the plume, the size distribution of droplets, sun angle and cloudy or hazy conditions. Under conditions of low visibility associated with a very moist atmosphere, it may become difficult to distinguish the cooling tower plume (U.S. Nuclear Regulatory Commission, 1976). On the other hand, the plume during clear, dry periods would be pronounced, especially when viewed at low sun angles with the sun behind the observer.

6.24 Observations at operating natural draft cooling towers show no instances of ground level fog and ice formation in areas of level terrain (U.S. Nuclear Regulatory Commission, 1976). There has been one reported case of a visible plume from a natural draft cooling tower reaching ground in mountainous terrain (Hosler, 1972). Predictive analyses of cooling tower plumes at Indian Point (U.S. Nuclear Regulatory Commission, 1975; 1976) show that ground level fogging might occur for 1 hour per year in addition to the average incidence of 79 hours per year of natural fog (defined as visibility of less than 1/4 mile at 33 feet above ground level). The potential for the formation of ice or frost at ground level or on structures in the path of the plume are negligible.

6.25 Only rough parallels can be drawn in the case of the Bowline Point Generating Station. A case-specific computer simulation would be needed to predict the risk of artifically producing these ground level phenomena, particularly in the area of the Hi Tor mountain to the southwest of the power plant. It may be anticipated, however, that the increase in the natural occurrence of fog and icing would be small, if at all discernible, in view of the relative infrequency of winds from the northeastern sector at the site and the absence of recorded observations of ground level and icing from operating natural draft cooling towers. No measurable increase in the incidence of fog and icing on level terrian around the site or on the river is expected. Studies relating to natural draft towers at Indian Point have shown that increases in ambient relative humidity as a result of moisture added to the atmosphere are inconsequential (U.S. Nuclear Regulatory Commission, 1976).

6.26 Under appropriate meteorological conditions, the rejected heat and water vapor could lead to the formation of cumulus clouds following the evaporation of the initial visible plume. This effect is most likely to occur where conditions are close to favorable for the natural formation of clouds and has been observed and recorded in a number of field studies (U.S. Nuclear Regulatory Commission, 1976). It is impossible to predict with any degree of certainty whether or where any detectable increase in precipitation might ensue. Cases of snowfall being induced by cooling towers have been reported (Kramer, 1976; Culkowski, 1962). The possibility exists that the amount of precipitation could be increased in a given locality as a result of moisture collected from the cooling tower plumes. A numerical model study of a specific application of a large natural draft tower in West Germany has shown that an increase of the order of 0.4 inches per year could be expected where the natural precipitation is 40 inches per year (Junod et al., 1974).

6.27 Noise. The operational noise level in large towers is generally in the range of 80 to 90 dBA (Edmonds et al., 1974). The noise from natural draft cooling towers is primarily that generated by falling water and the flow of large volumes of air through restricted spaces (U.S. Environmental Protection Agency, 1974). At short distances from the towers, the sound is "white" or broad spectrum sound, free of beats and impulses. During periods of continuous operation the sound remains constant in level and blends into background sounds (U.S. Nuclear Regulatory Commission, 1976). Propagation of the sound is affected by factors such as atmospheric absorption, topography, barriers, and vegetative cover.

6.28 A study of the offsite sound levels associated with the operation of closed-cycle cooling systems at Indian Point Unit 2 has shown that small increases in ambient noise can be expected in the vicinity of the plant, regardless of which type of cooling tower is selected (U.S. Nuclear Regulatory Commission, 1976). At 11 specific locations within 7,200 feet of the proposed tower (bordering the site, scattered in the Village of Buchanan and immediately across the Hudson River from Indian Point) the predicted increases rank from values below to values slightly above the threshold of detectability. The maximum increase in A-weighted day-night equivalent sound levels (L_{DN}) at any of the selected locations on the east bank of the river amounts to 0.5 to 1.5 dB for a natural draft cooling tower (the lower value applies to a cross flow tower and the higher value to a counterflow tower) and 1.4 dB for a conventional mechanical draft tower. The largest overall increase in L_{DN} amounting to 3.2 dB, would occur on the west bank of the river with a mechanical draft tower. All of the predicted increases are below the value considered likely to cause a change in community reaction to the noise (U.S. Nuclear Regulatory Commission, 1976).

6.29 Costs. Preliminary estimates (Orange and Rockland, December, 1974) of the costs (in 1981 dollars) of retrofitting natural draft cooling towers to the Bowline Point station are:

Equipment and Installation--Capital Cost*

Pricing base, December 1974	$38,250,000
Construction management, home office cost and construction fees	4,775,000
Escalation to July 1981	19,585,000
Orange and Rockland in-house expenditures	750,000
Allowance for funds during construction	6,400,000
	$69,760,000
Say	$69,800,000

Capitalized Operational Cost

Cost of capability derating (19 megawatts total)	$12,635,000
Heat rate penalty	13,953,328
Incremental replacement capacity lost	8,530,000
Operation and maintenance	1,431,000
	$36,549,328
Say	$36,500,000
Total	$106,300,000

6.30 The capital cost of equipment and installation (with a pricing base of December 1974) includes the cost of the cooling tower structures ($19,940,000 in 1974 estimate), circulating water pumps, pumphouse, piping, electrical instrumentation, blowdown dechlorination system, miscellaneous equipment, and civil engineering work. Distributable costs ($1,360,000) are computed on the basis of 25 percent of direct labor cost and include the costs of maintenance of tools and equipment, material handling, other unallocatable field labor, general and final job cleanup and consumable supplies. In

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*Capital cost estimates revised to December 1976, cost estimates have been further revised and updated (Orange and Rockland, 1977b).

addition, an allowance of 5 percent of field cost is included in the distributable costs as the contractor's fee. Contingency ($4,990,000) is computed on the basis of .15 percent of the field cost.

6.31 Escalation in total field cost ($38,250,000) is computed at the rate of 15 percent for 1974, 10 percent for 1975, 8 percent for 1976 and 7 percent compounded yearly thereafter. Escalation in home office costs is computed at the rate of 10 percent for 1974, 10 percent for 1975 and 8 percent for 1976 and years thereafter.

6.32 The cost associated with a total capability derating of 19 megawatts is computed at a rate of $665 per kilowatt installed in 1981. The heat rate penalty is based on a total generation of 6.3 billion kilowatt hours per year (1,200 megawatts operating at a capacity factor of 0.6) and an increase in net plant heat rate of 145 BTU per kilowatt-hour. At a cost of fuel of $2.67 per million BTU ($16 per barrel of residual oil, 6 million BTU per barrel) the yearly penalty in 1981 dollars amounts to approximately $2,440,000. The corresponding capitalized cost at 17.5 percent carrying charge over a 30-year balance of life of the plant is approximately $14 million. The incremental replacement capacity cost allows for a planned outage of each unit for 2 months during the transition to closed-cycle cooling, leading to a loss of 1.05 million kilowatt-hours of generation. The purchase of an equivalent amount of energy at $0.0326 per kilowatt-hour would require $34,250,000. Credit for fuel not consumed during this period at $2.67 per million BTU amounts to $25,270,000 yielding a net value of $8,530,000 for the incremental replacement capacity cost.

6.33 Operation and maintenance cost is estimated at $0.21 per kilowatt of net capacity per year. The total cost for the plant amounts to $250,000 per year and represents a capitalized cost of $1,431,000.

Evaporative Mechanical Draft Cooling Towers

6.34 The waste heat load from the Bowline Point Generating Station could readily be accommodated by evaporative mechanical draft cooling towers of proven design and performance. Available variations include the conventional linear towers with forced or induced air flow and circular towers consisting of a single large cell or multiple cells (U.S. Environmental Protection Agency, 1974; U.S. Nuclear Regulatory Commission, 1976). In addition, a variety of designs of natural draft cooling towers with fan assistance have been developed, and a few such devices are in use in Europe (U.S. Nuclear Regulatory Commission, 1976). For present purposes, fan-assisted towers are considered together with mechanical draft towers, since the primary intent in resorting to power assistance is generally to reduce the bulk (and visibility) of the cooling tower structure to proportions more representative of mechanical rather than natural draft towers.

6.35 Assuming a loading of 6 gallons per minute per square foot of base area (compared to the 4 gallons per minute per square foot in the natural draft towers considered above), heat rejection from each Bowline Point unit would require a mechanical draft tower with 63,000 square feet of base, or nominal dimensions of 75 by 850 feet. The overall height of the tower would range from 75 feet, typical of most tower designs, to 200 feet for fan-assisted natural draft towers.

6.36 Mechanical towers designed to the reference specifications and conditions would consume water through evaporation at substantially the same rate as their natural draft counterparts. Drift rates are normally higher, typically by a factor of 2 or 3 (U.S. Nuclear Regulatory Commission, 1976) in mechanical draft towers but, through appropriate design of drift eliminators, can be reduced down to levels well below the 0.05 percent of throughput assumed in the present analysis. The characteristics of blowdown from mechanical draft would be essentially the same as those of blowdown from natural draft towers.

6.37 Atomospheric Effects. Atmospheric effects associated with the release of warm moist air and drift are potentially more pronounced with mechnical draft towers than with natural draft towers. Since the release from mechanical draft towers is made at a lower elevation, where winds are generally weaker, the saturation deficit is less, surface nocturnal inversions frequently prevail and the plumes may be trapped in building eddies due to aerodynamic downwash, the potential for including fog and icing increases. On the other hand, visible plumes are generally shorter and lower, and long plumes occur less frequently (U.S. Nuclear Regulatory Commission, 1976). A comparative analysis of cooling alternatives for Indian Point Unit 2 (U.S. Nuclear Regulatory Commission, 1976) shows that the amount of salt deposited annually from mechanical draft towers is higher, by a factor of approximately 6 in areas of maximum deposition, than is the case with natural draft towers.

6.38 Several studies have reported light, friable icing from the operation of mechanical draft towers, but there have been no reports of severe icing on roads or structures adjacent to the towers. In most cases fogging and icing would be confined to distances of 1,000 to 2,000 feet from the tower (U.S. Nuclear Regulatory Commission, 1976).

6.39 Costs. Capital costs associated with mechanical draft cooling towers are generally lower than those associated with natural draft towers. Annual operating costs, on the other hand are higher, particularly since the operation of mechanical towers involves a substantially higher consumption of power. The cost advantage of one system over the other can be established only through detailed analysis where such factors as the cost of energy can be assigned appropriate weights. In a retrofit application, as is the case at the Bowline Point station, the relative difference in total costs is expected to be minor, and, in view of the high cost of energy associated with fuel oil, it is assumed that mechanical draft towers represent a greater cost penalty than do natural draft towers.

Cooling Ponds

6.40 The minimum surface area of a cooling pond needed to reject the waste heat from the Bowline Point station is estimated to be 750 acres. This estimate is based on a thermal loading of 6.9 million BTU per hour per acre (roughly equivalent to 0.6 acres per megawatt of installed capacity) and meteorological conditions prevailing in New York City (Patterson et al., 1971). Evaporative water losses from the pond would average 6.7 million gallons per day (4,700 gallons per minute). Drift losses from cooling ponds are caused by surface winds and are generally considered negligible. The quantity and frequency of purge needed to maintain the concentration of dissolved substances in the pond at acceptable levels are unlikely to exceed the values associated with blowdown from cooling towers (average of 3,300 gallons per minute).

6.41 A cooling pond is considered to be impractical at Bowline Point because of the unavailability of an adequate expanse of suitable land in the vicinity of the generating station. The land requirements, however, could be substantially reduced through the application of spray devices designed to produce fountain-like jets of water and increase the dissipative effectiveness of a unit of surface area of pond. With full spray assistance, the required area could be reduced by a factor of 20 (McKelvey and Brooke, 1959; U.S. Nuclear Regulatory Commission, 1976). A spray pond to serve the Bowline Point station would require a minimum of 38 acres. In principle, therefore, the 53-acre Bowline Pond could serve as a spray pond to meet the cooling needs of the station. The conversion would entail the isolation of the Bowline Pond from the Hudson River at the pond inlet, with provisions made for the intake of makeup water and the discharge of blowdown.

6.42 As a first approximation, the evaporative losses from a spray pond are of equal magnitude to those from a passive cooling pond in comparable service. Spray cooling, however, generates substantial quantities of drift, estimated to amount to 0.2 percent of the water circulated through the condenser (Roffman and Van Vleck, 1974). In the case of Bowline Point station, drift losses would amount to 750 gallons per minute. Drift, together with fogging and noise, might give rise to unacceptable problems in view of the proximity of residential sections to the west and south of the pond and the Bowline Point recreational facility to the east of the pond. A buffer zone of 1,000 to 1,500 feet is needed to confine fogging and drift effects to the site (U.S. Nuclear Regulatory Commission, 1976), implying that spray modules would have to be carefully positioned in the pond. Further detailed engineering and economic analyses are needed to determine whether the spray pond alternative warrants further consideration.

Dry Cooling and Wet-and-Dry Cooling Towers

6.43 Operating experience with both dry cooling and wet and dry cooling applied to steam electric power plants is limited. Dry cooling has a long history of application to small power plants particularly in Europe and Africa. The dry cooling technique in common use, known as the direct technique, is generally not considered practical for applications to power plants with capacities larger than 350 to 500 megawatts. In the United States, a 330-megawatt coal-fired power plant in Wyodak, Wyoming will be equipped with a direct cooling system and is scheduled for completion in the near future. The cooling facility will be used in a 5-year test program, funded in part by the U.S. Department of Energy and is aimed at improving dry cooling design and operation (U.S. Department of the Interior, 1974). A second method of dry cooling known as the indirect technique is considered to be conceptually suitable for application to large power plants. There are currently no firm plans to use a system of this type in a large central station.

6.44 Both natural draft and mechanical draft towers can be used in dry cooling systems. Since the flow of air required to dissipate a given heat load is higher with dry cooling than with evaporative cooling, dry cooling towers are necessarily more massive than their evaporative counterparts. Further, the minimum temperature (of the cooling water) attainable with dry cooling is higher than or equal to the minimum temperature attainable with evaporative cooling systems (Appendix D). The penalties, in terms of loss of generating capacity and reduced operating efficiency, are correspondingly higher. Under conditions prevailing at Indian Point Unit 2, the cost of energy generated with dry cooling is estimated to be 20 percent higher than the cost of energy generated with once through cooling and 15 percent higher than the cost of energy generated with evaporative closed cycle cooling.

6.45 Several schemes have been proposed to combine dry and evaporative cooling systems and derive the benefits of dry cooling while reducing the associated penalties. A typical design objective would be to have dry cooling in operation during 95 percent of the year and resort to evaporative assistance (or, possibly, other means such as mechanical refrigeration) when ambient temperatures are highest. The idea is particularly attractive where the peak demand for power occurs during the hottest part of the year and coincides with the greatest loss of generating capacity attributable to dry cooling.

6.46 The greatest potential advantage of dry or wet and dry cooling at the Bowline Point station is associated with the reduced need for makeup water to offset the losses due to evaporation, drift and blowdown. As presently contemplated, however, an evaporative cooling system at the station could be supplied with water withdrawn to meet the power plant's service requirements. Without reducing the service requirements, this advantage would be virtually negated.

Other Cooling Alternatives

6.47 A number of other cooling alternatives might prove to be technically feasible at the Bowline Point station. The first of these is to meet the cooling needs of both units with a single evaporative cooling tower to accomodate the heat rejection load, the base area of a single tower would need to be roughly twice that of a tower designed to reject the waste heat from one of the units. In the case of a natural draft tower a commiserate increase in height would be needed to generate a flow of air adequate to effect the desired degree of cooling. Thus, a single tower would necessarily be more massive than a tower used in a dual system. In the case of a mechanical draft tower, the total number of "cells" or modules would be the same, whether these make up a single or a dual cooling system. A single tower, therefore represents a reconfiguration of the cells into a single array. From a visibility standpoint the tradeoffs involved in changing from a dual to a single system are evident. Whether this change would reduce this visual impact of the cooling system and the station as a whole remains uncertain in the absence of further study.

6.48 A second possibility is to site a single or dual tower at a location remote from the generating station. Distances of 5 miles or more between the generating station and cooling tower may be technically feasible, taking into consideration a rate of flow of approximately 375,000 gallons per minute through each of the units, a total rate of makeup of 16,000 gallons per minute and an estimated rate of blowdown of approximately 7,000 gallons per minute from the system. Conducts linking the station to the cooling system would be needed to carry the circulating water and makeup water, if the service water system is retained as the source of makeup. A conduit for the discharge of blowdown would be needed to link the cooling system to the Hudson River, the most likely waterbody to receive the discharge.

6.49 Although it is impossible to estimate the penalty in capital costs associated with a remotely sited cooling system until a precise location is selected, it may be anticipated that this penalty would be substantial. An economic penalty as well as a penalty in terms of energy would be incurred in operating the systems, that is in pumping water between the station and the cooling towers. Again, this penalty would be dependent on the separation between the facilities and, in view of the large flow rate involved is expected to be substantial.

6.50 The primary incentive in considering a remote site for the cooling system lies in reducing the visibility of the generating station with cooling towers from the Hudson River. It appears unlikely, however, that cooling towers with their plumes could be entirely concealed from the view, particularly in the case of natural draft towers. Clearly, a remotely sited cooling system would constitute a visual impact in its vicinity. In essence, therefore, a remotely sited cooling system represents a tradeoff between reducing the combined visual impact of the generating station with a closed cycle cooling system at the expense of creating two visual intrusions at separate locations. Over and above this, there remain the questions of costs, securing a suitable site, installing the necessary conduits over appropriate right-of-ways and public acceptability of the overall scheme.

6.51 Salt drift from the cooling towers has been identified and analyzed as a potential source of damage to vegetation in the vicinity of the Bowline Point station (Chapter 4). An alternative considered here to reduce the deposition of salt involves reducing the concentration of dissolved matter in the cooling water inventory. This could be accomplished by treating the makeup water, which may consist of river water and recirculated blowdown, or by obtaining and, if necessary, treating water from groundwater, municipal or other sources. As mentioned previously, a total of 16,000 gallons per minute is presently drawn as service water from the Hudson River to meet the needs of the station and the major portion of the flow could be made available as makeup for a closed-cycle cooling system. This withdrawal is equivalent to approximately 23 million gallons per day, or, on the basis of a planning factor of 100 gallons for person per day, enough water to supply a residential community of 230,000 persons. In terms of a ground water supply, yields from individual wells vary greatly with the properties of the aquifers supplying the water. To put matters in perspective, it may be noted that a well yielding 0.5 to 1 million gallons per day is generally considered to be a high capacity well. Precise estimates of the costs of desalinating river water to reduce its salinity are not available. Major desalination and treatment projects based on the reverse osmosis process are presently under construction in various parts of the world. As a general rule, the costs associated with desalination fall in the range of $0.80 to $1.30 per 1,000 gallons treated. To meet the needs of a closed-cycle cooling system at the Bowline Point station, therefore, would entail an expenditure of the order of $20,000 per day.

6.52 Another possibility which could be considered as an alternative to a closed cycle system, consists of modification to the intake structures, including barriers at the entrance to Bowline Point to reduce entrainment and impingement. These are considered in detail elsewhere in Chapter 6.

6.53 Finally, waste heat from the Bowline Point station could in principle be rejected to the Hudson River through an underwater heat exchanger. The cooling system would be entirely closed and once filled, would require only minimal makeup. While heat exchangers of appropriate design are readily available, an application of the type and scale envisaged here cannot be considered as demonstrated technology. Accordingly, the costs and reliability of such a system cannot be predicted with any degree of confidence.

Modification of the Present Permit

6.54 The specific conditions, considered as possible stipulations that might be added to the permit issued by the District in connection with the Bowline Point Generating station, all relate to the station's interactions with the aquatic ecosystem of the Hudson River estuary. These conditions are intended to mitigate damage to populations to striped bass and other fishes. Several approaches could be followed, in principle, to attain this goal. Restrictions could be imposed on the operation of the power plant so as to reduce the throughput of cooling water, thereby reducing entrainment and impingement of aquatic organisms. An alternative approach would be to reduce the impingement of fish by installing fish diversion devices and/or by modifying the intake structure, screening mechanisms and fish return facilities. Entrainment could not be reduced significantly through these latter means. Elements of both approaches might be combined into a number of more comprehensive strategies. From an operational standpoint, such strategies might involve the integration of the generation and maintenance schedules of the power plants on the Hudson River estuary and other power plants within the New York Power Pool supply system, on the basis of ecological as well as technical and economic factors.

Restricting Operation of the Plant

6.55 Measures aimed at reducing the amount of cooling water that is withdrawn from the Bowline Pond and circulated through the power plant might include restrictions to the operating schedule of the plant, reduced flow through the condenser, and operation of the plant at partial generating capacity. However, technical considerations relating to a large base-load plant like the Bowline Point Generating Station tend to limit the extent to which the plant can be operated intermittently or at reduced output. Also limited is the extent to which operating procedures can deviate from standard practices without unduly jeopardizing the plant and the reliability of the supply system.

6.56 Shutdown and startup of large steam electric units involve procedures formulated to avoid excessive thermal stresses, overheating and other conditions likely to damage the equipment. Following a shutdown, time is needed to bring the boiler and turbine generator up to operating conditions in steps that are generally more sequential than concurrent. Progressively longer procedures are followed as generating units are started up from hot, intermediate or cold conditions and these, as a general rule, prevail after shutdowns of 1 day or less, 2 to 3 days, or 3 days or more, respectively. The startup periods may range between less than 1 hour for a start from hot conditions and 6 to 12 hours or more for a cold start. Recent development work and evaluations of operating experience have underscored the importance of controlling downward temperature ramps and prewarming during cold starts, in terms of preventing damage to steam turbines and extending their operational lives (Spencer and Timo, 1974). These findings have prompted the manufacturers of turbines to recommend that warmup periods generally be extended rather than shortened.

6.57 Startup of the condenser cooling or circulating water system is also a lengthy procedure. A rapid initiation of the massive circulation subjects the equipment to a risk of damage as a result of water hammer, and steps must be taken to ensure that the system is free of air pockets before full flow is established. Procedures normally followed at the Bowline Point station require 8 to 12 hours to bring the circulating water systems up to operating conditions.* As a consequence, water is circulated in the systems at all times except during maintenance outages or other prolonged periods when the generating units are taken out of service. The flow may be reduced (1 pump per unit) when a unit is not producing power

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*Established in discussion with Orange and Rockland operating performed during site visit on 3 and 4 November, 1976.

but is generally kept at operational levels (2 pumps per unit). Flow is maintained with 2 pumps per unit operating whenever power is being generated to avoid the risk of losing a unit as a result of one pump failing.

6.58 Large generating units can operate at capacities greater than 1/4 to 1/3 of full-rated capacity (150 to 200 megawatts for each of the Bowline Point units). The quantity of waste heat rejected to the condenser cooling water varies proportionally with the power and, accordingly, the temperature rise across the condenser decreases as power is reduced, providing the circulation rate remains constant.

6.59 Each of the Bowline Point units has the capacity of operating with reduced flow in the condenser cooling system. Under throttled conditions, the flow is reduced from 316,000 to 257,000 gallons per minute through each condenser with 2 pumps per unit in operation. The temperature rise across the condenser at full load increases from 13.5 F to 16.6 F as the flow is reduced. Alternatively, a temperature rise of 13.5 F would prevail with reduced flow at 80 percent of full load, decreasing to a rise of approximately 4 F at 25 percent of full load.

6.60 Both units of Bowline Point station have been operated extensively with cooling water circulating at the reduced rate. In 1975 a circulation rate of 257,000 gallons per minute was maintained in both units practically continuously from the first days in January through the latter part of July (except during the maintenance outage of unit 1 from 8 May to 31 May, 1975).* Operating experience showed that the reduced velocity of water through the condenser tubes (from a design value of 7 feet per second to an estimated 5.5 feet per second) allowed slime to build up at higher than normal rates. Orange and Rockland has modified its procedures and now operates the units at reduced flow only when necessary to reduce impingement of fish or for other reasons related to the aquatic ecosystem.**

6.61 The characteristics of the Orange and Rockland system load (Appendix C) are pertinent factors in considering restrictions that might be imposed on the operation of the plant. Electrical load in southeastern New York, as in most areas of the country, generally increases during daylight hours, reaching pronounced peaks on weekday afternoons and evenings, and less pronounced peaks on weekends and holidays. The annual peak load of approximately 650 megawatts normally occurs on a weekday afternoon in July or August,

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*Established from plant operating records made available by Orange and Rockland.

**Established in discussions with Orange and Rockland personnel during site visit of 3 and 4 November 1976.

with demand remaining near peak conditions roughly between mid-June and mid-September. Load is relatively high between mid-December and mid-February and a secondary peak of the order of 500 megawatts is experienced in late fall or early winter. Monthly output of the system is lowest in April and May of each year. Further, Orange and Rockland's 1/3 share of the Bowline Point station represents a generating capability of 401 megawatts, equivalent to 44 percent of the company's base load capability and 39 percent of total generating capability (Appendix C). Con Edison's share of the plant, amounting to 803 megawatts, constitutes 10 percent of the system base load capability and 8 percent of total capability.

6.62 The least restrictive operating schedule for the Bowline Point station can be characterized as "last-on-first-off," meaning that alternative resources available to Orange and Rockland and Con Edison would be utilized before power is generated at the Bowline Point station. A schedule of this type was followed in 1974 during the last 10 days in May and the months of June and July, in accordance with the terms of the consent decree (Appendix B). Operation of both units at the Bowline Point station was restricted in that period to approximately 50 percent capacity until all available base load capability was committed to full load operation. The output of the Bowline Point station was then increased to meet any excess base load (continuous load) and cycled to follow fluctuations in demand of intermediate duration (12 or more hours on weekdays). Gas turbines were used in a normal manner to meet peak demand (less than 1 hour to about 12 hours). Operational data for the period show that both units were operated below full capacity during June and July. However, the amount of water circulated through the condensers was not substantially reduced, except during the last 10 days in May. Both units were off line at the time, on scheduled outage or for repairs, and no water was circulated through the plant condensers.

6.63 More restrictive conditions on the operation of the plant can be envisaged. As constraints are added, however, an increasingly larger portion of the base load would be shifted from the Bowline Point station to plants that would otherwise be retained for cycling duty. There would be an attendant penalty in fuel use and economy of generation, since such plants are generally the older, less efficient units within the system--the Lovett station in the case of the Orange and Rockland system. A further tradeoff might be involved, inasmuch as the substitute plants exert particular impacts on the environment and these might be intensified as a result of increased utilization. While current procedures and practices are followed, water would continue to be circulated through the Bowline Point station at times when its operation is restricted unless protracted shutdowns become part of the restrictions. The present overcapacity in the Orange and

Rockland, Con Edison and New York Power Pool Systems would make it possible to meet demand during most of the year for the next several years without the contribution of the Bowline Point station except when demand is at or near peak levels. Orange and Rockland would then be unable to meet its commitments from resources presently available to the system (Appendix C).

6.64 It is impossible to estimate with any degree of certainty the net advantages that the aquatic ecosystem of the Hudson River Estuary would derive from restrictions on the operation of the Bowline Point station. If circulation is maintained through the condenser cooling system while the plant is restricted to low power on zero power operations, there would be no net gain with respect to impingement. As regards entrainment, a reduction or elimination of the thermal shock undergone by aquatic organisms that pass through the condensers is advantageous. Thermal shock, however, is not the sole mechanism through which biota are injured or destroyed. Other potential causes of damage have been identified (see papers by J. R. Schubel, R. E. Manowicz and B. C. March, Jr., in Saila, 1975). These include pressure changes, acceleration, shear, abrasion, biocides when used, and possible synergisms among them. Field data collected at Bowline Point station indicate that mortality of fish larvae entrained through the plant tends to increase as the temperature rise across the condenser increases and that temperature is the main determinant of mortality among entrained organisms (Orange and Rockland, 1977a).

Improvements to Plant Intake

6.65 Ongoing research related to the protection of aquatic organisms at power plants (reviewed in, for example, Pagano and Smith, 1977; Cannon et al., 1979) suggests that several alternatives to the conventional vertical screen intake of the type installed at the Bowline Point station might be effective in reducing impingement. For convenience, these alternatives may be considered under the categories of diversion, recovery and exclusion systems, although a classification according to this scheme would not be rigorous and certain unconventional intakes may combine the features of systems classified in more than one category. Diversion systems include those based on behavioral barriers such as electric fields, air bubble curtains, sound, light, water jets and hanging chains (U.S. Environmental Protection Agency, 1976) as well as louvers and angled screens (U.S. Environmental Protection Agency, 1976 and, for example, Schuler and Larson, 1975; Taft et al., 1976; Taft and Mussalli, 1977; Mussalli et al., 1977). Recovery systems provide means of collecting impinged organisms and returning them to water. Several fish handling transport systems have been developed and tested (for example, Mussalli and Taft, 1977) and these may be used to recover organisms impinged on conventional traveling screens (for example, Eisele and Malanic, 1977) or screens of alternative designs, such as the fish bucket screen (for example, White and Brehmer, 1976) or the center flow (single-entry, double-exit) screen (for example, Passavant Corporation, undated). Exclusion systems incorporate physical barriers to prevent organisms from entering the intake structure. Among them are the infiltration devices, such as radial wells, fixed bed filters and porous dykes (U.S. Environmental Protection Agency, 1976) and wedge wire screens (for example, Johnson Division, UOP, 1977; Hanson et al., 1977; Key and Miller, 1977). Infiltration intakes eliminate or reduce entrainment as well as impingement. Other intakes that have the potential of reducing entrainment incorporate either woven screening of fine mesh (Tomljanovich et al., 1977) or wedge wire screens with narrow slot widths (Hanson et al., 1977).

6.66 Six schemes have been identified as possible alternatives or modification to the existing intakes at the Bowline Point Generating Station (Orange and Rockland, 1976). The selection of these specific schemes is based on considerations of engineering practicality and the results of flume tests with certain native fishes of the Hudson River (Consolidated Edison, 1976) as well as experience and an increasingly wide body of information reported in the literature. Four of these schemes involve traveling screens of conventional but angled or inclined to the direction of flow. In the first scheme, an approach channel would be constructed to provide the necessary angle between flow and the existing intake structure. The next two schemes involve traveling screens in a chevron configuration located respectively to the side and in front of the existing structure. The fourth scheme comprises screens located in front of the existing structure, positioned perpendicularly to the direction of flow but rotating about a plane inclined from the vertical. As part of the fifth scheme, the existing traveling screens would be replaced by fish bucket screens. A fish bypass or collection and return device would be provided in each of these five schemes. In the sixth and final scheme, a behavioral barrier would be placed at the inlet of Bowline Pond. Three possible mechanisms have been identified as possible means of diverting aquatic organisms away from the pond--an air bubble curtain, hanging chains or a water jet curtain. Any one of the suggested schemes could be implemented without disrupting the normal operation of the plant. Detailed estimates of the costs associated with these schemes are not available. Orange and Rockland considers to be in the range of $5 to $10 million.

6.67 In addition to evaluating the alternative intakes discussed above, Orange and Rockland has been testing a barrier net positioned in a V upstream of the existing intake structure (Edwards and Hutchison, 1979). The results of tests conducted at various times between November 1976 and May 1978 suggest to the investigators that impingement may be reduced by as much as 90 percent (see Chapter 4). Clogging of the screens and the gilling of fish on the nets are reported not to be significant problems. Further evaluation is needed to determine whether a barrier net could be considered as a permanent alternative to the modified intakes and whether reductions in impingement comparable or exceeding those reported for the barrier net could be achieved with the alternative intakes identified by Orange and Rockland. In addition, the selection and implementation of one particular scheme as the most suited to the situation at Bowline Point would be contingent on more extensive and detailed evaluations. It may be well to note that entrainment would not be significantly reduced through the application of any one of these techniques. Tests of a continuously traveling screen with fine mesh (2.5 millimeters) woven netting conducted at the Indian Point station suggest to the investigators that such a system would not be effective in reducing losses of striped bass in the early stages of life (Central Hudson et al., 1979). This conclusion is based on the low retention rate of eggs and larvae up to the early post yolk-sac stage and the low rate of survival among the organisms retained on the screen. Among the organisms large enough to be retained in substantial proportions, the rate of survival is reported to be comparable or less than the rate expected to prevail if the organisms were entrained through the condenser.

6.68 In view of the need for further evaluation of possible modifications to the intake existing at the Bowline Point station as well as the cost and extent of work associated with the modifications identified by Orange and Rockland, operational restrictions based on improvements of the intake are considered by the District to be more appropriately regarded as alternatives to closed-cycle cooling than as conditions that could be imposed during an interim period of operation with one-through cooling. With respect to the aquatic ecosystem of the Hudson River estuary, any reduction in the rate of impingement of aquatic organisms clearly would tend to mitigate the impacts attributed to the operation of the power plants on the river. How effective such mitigation would be in terms of populations of fish is presently unknown because of the several uncertainties discussed above and the absence of plans to take specific measures at specific power plants.

Comprehensive Management Program Within the New York Power Pool

6.69 A broad view of the ecosystem of the Hudson River estuary suggests that a comprehensive approach at managing the operation of all the power plants on the river could prove more beneficial than restricting the operation of individual plants in isolation of each other. Such an approach might incorporate considerations of the numerous species of fish that inhabit the river, their spawning and migrating habits, nursery areas, and other temporal and spatial characteristics of their life cycles.

6.70 It is conceivable that the integrated supply system of the New York Power Pool could afford the flexibility needed to develop a management strategy of power plant operation based on ecological as well as technical and economic factors. Scheduled maintenance and generation plans of the stations throughout the power pool area could possibly be coordinated to avoid affecting critical areas during critical periods or, at least, mitigating ecological damage to the extent possible with present constraints. For example, the strategy could take advantage of the temporal and spatial differences in entrainment and impingement among the power plants on the Hudson River (see discussions of entrainment and impingement in Section 4). The Bowline Point station might be operated during the primary spawning season (May and June) because of its smaller entrainment rate relative to other power plants. Other stations could be shut down for maintenance or restricted in their operation during this time, which also corresponds roughly to the spring period of low demand for electricity. In winter months when impingement is greatest at downriver plants, their operation might be restricted. Upriver plants, which cause less damage by impingement during the colder months, or plants located elsewhere in the power pool area could then be utilized more extensively to supply the needed energy. Clearly, these are suggestions derived from limited ecological information. Further analysis of available observations and acquisition of additional data would be needed to determine whether a management program of the type envisaged here would be beneficial from an ecological standpoint and, if so, to devise a comprehensive and balanced strategy. It may be well to note that the addition of ecological constraints to the technical and economic constraints presently acting on the supply system is likely to involve tradeoffs and entail costs in terms of economy and reliability of supply.

Suspension of the Permit

6.71 The District has considered a suspension of the subject permit, causing the Bowline Point Generating Station to shut down and not resume operation until a closed-cycle system is installed.

6.72 With an accelerated program of construction and commissioning, closed-cycle cooling systems at the Bowline Point station could be brought into operation within an estimated minimum period of 2 to 3 years. During this period, the generating capacity of the Bowline Point station would be unavailable to Orange and Rockland, Con Edison and the New York Power Pool. Orange and Rockland would be unable to meet its projected peak load from alternative new resources available to the company (Appendix C). On the other hand, overcapacity in both the Con Edison and New York Power Pool systems is currently such that available capability in both systems, even without the contribution of the Bowline Point station, exceeds peak demands anticipated over the next several years with acceptable margins of reserve (Appendix C).

6.73 Suspending the operation of the Bowline Point station represents a loss of operating revenues to the plant owners estimated to be in excess of $300 million per year.* Assuming the alternative generating and transmission capabilities are such that the loss of energy could be sustained without interruption of customer service, increases in fuel use and the cost of generating electrical energy are likely to result from a shutdown of the Bowline Point station. The precise magnitude of these penalties would depend principally on the thermal efficiency of the plants that generate the replacement power and, to a lesser extent, on likely additional losses in transmission. Increased fuel consumption would amount to an estimated 1.75 million barrels of fuel oil per year, with a corresponding value of $26 to $28 million.*

Revocation of the Permit

6.74 The District has considered revoking the subject permit, forcing the abandonment of the Bowline Point Generating Station.

6.75 The implication of this action would be far-reaching. As indicated previously, Orange and Rockland would be unable to meet peak loads from resources presently available to the company over the next several years without the contribution of the Bowline Point station (see Appendix C). Decommissioning the power plant would

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*Estimate based on net plant rate of 8,135 BTU per kilowatt-hour at the Bowline Point station and a heat rate of 11,000 BTU per kilowatt-hour, typical of electrical energy generation from fuel oil in the Middle Atlantic States (National Coal Association, 1975). Each kilowatt-hour generated at the Bowline Point station then represents a saving of 1,865 BTU. The 5,600 gigawatt-hours that would have to be generated by other stations represent an additional consumption of 10,500 BTU. At $15 to $16 per barrel of No. 6 fuel oil with a maximum sulfur content of 0.3 percent, the corresponding added consumption and costs are 1.75 million barrels and $26 to $28 million, respectively.

involve a substantial loss in tax revenue to the Town of Haverstraw until the Bowline Point site is redeveloped for industrial or other use. The Bowline Point station represents an investment (current cost of plant) of $250 million, exclusive of land and land rights, with a replacement value of approximately $1 billion in 1985 dollars.*

6.76 A relatively minor portion of the investment could be recovered as salvage if the plant were to be abandoned. Further benefits would be derived through the addition of replacement capacity that, in all likelihood, would not be oil-fired, and if coal-fired, might be slightly more efficient than the present equipment. The ultimate decommissioning of the plant would also remove a dominant visual feature from the vicinity of Bowline Point. As regards the population of striped bass in the Hudson River, very little would be gained by abandoning the Bowline Point station as opposed to installing closed-cycle cooling at the plant.

ALTERNATIVES RELATED TO THE ROSETON GENERATING STATION

6.77 The options available to the District in the case of the Roseton Generating Station are essentially the same as those discussed previously in connection with the Bowline Point Generating Station, namely, to retain, modify, suspend or revoke the District's permit issued to Central Hudson. The Bowline Point and Roseton Generating Stations are technically similar and their interactions with the environment are comparable in nature, if not precisely in degree. Accordingly, the implications associated with each of the alternative actions follow close parallels in both instances.

Retention of the Present Permit

6.78 The terms of the National Pollutant Discharge Elimination System permit authorizing the discharge of waterborne contaminants from the Roseton Generating Station require that operational levels of closed-cycle cooling be attained by 1 July 1981. Retention of the District's permit to Central Hudson, therefore, would allow a period of unrestricted operation of the plant with open-cycle cooling until 1 July 1981 or throughout the operational life of the plant, if the

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*A breakdown of the current cost of plant is: land and land rights $1,100,760, structures and improvements $42,772,050, equipment costs $207,225,810, representing a total cost of $251,098,630 or $202 per kilowatt installed (U.S. Federal Power Commission, Form 1, Annual Report of Orange and Rockland Utilities, Inc. for year ended 31 December 1976. Replacement costs are computed on the basis of $820 in 1985 dollars per kilowat of installed coal-fired capacity.

requirement for closed-cycle cooling at the Roseton station is ultimately waived by the U.S. Environmental Protection Agency.

6.79 The impacts resulting from the operation of the Roseton station with open-cycle cooling are those documented in Chapter 4 of this statement. The major advantage of installing closed-cycle cooling at the facility stems from reducing the potential of damaging the aquatic ecosystem of the Hudson River by reducing the rate at which cooling water is withdrawn and discharged. To accomplish this goal, the installation of any one type of closed-cycle cooling system found to be practical for the Bowline Point station is considered technically feasible at the Roseton station. The related monetary costs and other impacts, such as land and water use, the release of water vapor and spray to the atmosphere, noise and the visual features of the cooling system, would be similar to those associated with closed-cycle cooling at the Bowline Point station.

6.80 Without additional encumbrances imposed by the District, the Roseton station would continue to generate electrical energy as efficiently, reliably and economically as possible and to satisfy, in part, the needs of residential, industrial, commercial and public consumers served by Central Hudson, Con Edison, Niagara Mohawak and the New York Power Pool (Appendix C). The transition to closed-cycle cooling, if carried out within the time frame currently specified in the National Pollutant Discharge Elimination System permit, would be orderly.

Modification of the Present Permit

6.81 Concern over the continued operation of the Roseton facility, in common with the other power plants on the Hudson River Estuary, centers principally on the impairment of the aquatic ecosystem as a result of entrainment and impingement of organisms. Estimates based on the field data available suggest that the number of organisms entrained by the Roseton station may be substantial in comparison to other plants but mortality due to impingement is relatively minor. The analysis dealing with striped bass shows that the impact attributable to the operation of the Roseton facility with once-through cooling is small in terms of the net effect on the adult population and in comparison to the overall effect of all power plants on the Hudson River. The installation of closed-cycle cooling at the Roseton station alone, with all other stations remaining on open-cycle cooling, would reduce the riverwide losses of yearlings and the adult standing stock by only a small amount below the losses predicted for all plants with once-through cooling.

6.82 On the basis of these findings, measures to reduce the intake of cooling water by restricting the operation of the Roseton station and to reduce impingement through modification of the intake structure or behavioral screening systems would be of lesser value at the Roseton station than at the Bowline Point station. In the context of a comprehensive (including environmental considerations) program to manage the operation of power plants on the Hudson River and in the New York Power Pool, steps could be taken to utilize the Roseton facility sparingly at times when entrainment of fish eggs and larvae might present a problem, and more intensively at times when the operation of other plants within the system would be most detrimental from an ecological standpoint. It is emphasized that statements made here in connection with alternatives related to the Roseton station are based on limited field data collected in 1974, when both units were first brought into service, and early in 1975. These statements would remain valid largely if field monitoring continues to reveal a relatively low level of impact on the aquatic ecosystem resulting from the operation of the Roseton station.

Suspension of the Permit

6.83 A suspension of the District's permit related to the Roseton Generating Station would cause the station to be shutdown for an estimated 2 to 3 years while closed cycle cooling is installed. Without the contribution of the Roseton station, both Central Hudson and Niagra Mohawk would experience difficulty in maintaining an adequate margin of reserve with the remaining resources currently available to these systems (Appendix C). Reserve margins in the Con Edison and New York Power Pool would not be reduced below acceptable levels in the near-term future if the Roseton station were to be shut down temporarily (Appendix C).

6.84 Suspending the operation of the Roseton station represents a loss of operating revenues to the plant owners estimated to be of the order of $300 million per year. The generation of replacement energy by alternative power plants is likely to involve an increased usage of older, less efficient equipment with a corresponding penalty in fuel consumption. The increased fuel consumption is estimated to be of the order of 2.5 million barrels of fuel oil per year, with a 1976 spot market value in excess of $37.5 to $40 million per year.

6.85 Suspending the Roseton permit during the 2 to 3 years necessary to build cooling towers would result in only a negligible incremental benefit to the striped bass population.

Revocation of the Permit

6.86 Revocation of the Roseton permit would lead to the abandonment of the station currently valued at $250 million, exclusive of land and land rights (U.S. Federal Power Commission, Form 1, Annual Report of Central Hudson Gas and Electric Corporation for year ended 31 December 1976). The replacement value of the generating capacity is estimated to be in excess of $1 billion in 1985 dollars. In terms of the population of striped bass in the Hudson River, the analysis discussed previously shows that relatively little would be gained by abandoning the station as opposed to installing closed-cycle cooling at the station.

CHAPTER 7

THE RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

7.01 The relationship between the short-term use of the Hudson River for power generation and the long-term productivity of the estuary may be considered in terms of spreading urbanization on the one hand and the inherent value of the natural resource on the other. Both the Bowline Point and Roseton generating stations form part of a broad pattern of urbanization in the lower Hudson River Valley. Together with other existing power plants on the river, they represent examples of the traditional practice of locating generating facilities in relative proximity to the load centers they serve, on sites with adequate supplies of water to satisfy the operational needs of the power plants and capable of accommodating modest expansions of the facilities.

7.02 As such, the stations introduce no new trends in siting and neither strongly promote nor inhibit human development of the area. The visual prominence of the stations contributes heavily to the industrial character of the riverfront in their vicinities, but, by virtue of their locations and the long-established tradition of industry and commerce on the river, the stations are not unique features. There is no evidence that the presence of the power plants has given rise to any unusual pattern of land use in the valley nor that future land use plans might be unduly influenced by the existing facilities. Nonetheless, the stations are visually obtrusive and may be regarded as a detraction from the natural scenic beauty of the valley. In this respect, they do represent a compromise of the long-term productivity of the area.

7.03 Man's influence on the Hudson River estuary has been sufficiently extensive and prolonged to alter virtually all of the native upland ecosystems of the valley. The varied land forms, however, provide habitat for a number of plant and animal species, reflecting in their diversity and distribution the past and present uses of land on the riverbanks.

7.04 Despite development of the shoreline for industry, transportation, agriculture, residential and recreational uses, and the effects of a long history of water pollution, the wetlands remain productive. The aquatic ecosystems of the estuary, although altered somewhat by man's activities, in all likelihood remain essentially those present before intensive settlement of the area, notwithstanding the evident reduction in sturgeon, shellfish and other characteristic aquatic life. There is little doubt that the biological productivity of the area has been diminished by some of man's previous and continuing activities on the estuary. Regarding these activities as short-term uses of the environment, it is clear that long-term productivity of the estuary has been reduced. To the extent detailed in Chapter 4, the Bowline Point and Roseton Generating Stations as well as the other power plants on the Hudson River estuary give rise to impacts and, thus, can be considered in terms of short-term uses of the environment. A remote possibility exists that the continued operation of these power plants will lead to irreversible changes (Chapter 8).

CHAPTER 8

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

8.01 The Bowline Point and Roseton Generating Stations are major engineering projects that represent a substantial commitment of resources. Materials, energy and labor have been irretrievably committed in constructing the power plants. Their operation involves a continuing commitment of fuel oil and labor. Rejection of waste heat from the power plants promotes evaporation of the condenser cooling water or a loss of water to the atmosphere. With respect to the Hudson River estuary as a water resource, this loss may be regarded as irretrievable. Land dedicated to the power plants and related facilities, although not an irreversible or irretrievable commitment in the strictest sense, is likely to remain in use for power generation or other industrial purposes well beyond the operational life of the present generating units. The commitment of land to industrial purposes may be considered permanent. Biological resources have been and continue to be committed. A reduction in biological productivity results from the removal of potential habitat for fish and wildlife by the power stations and their continued interactions with the environment. Of primary concern are the impacts that the power plants exert on the aquatic ecosystem of the Hudson River. The operation of the power plants lead to the destruction of fish and other aquatic organisms. Their loss to the ecosystem is irretrievable. The question of whether this loss will lead to a significant alteration or an irreversible change of the ecosystem has not been fully resolved.

COMMITMENTS AT THE BOWLINE POINT GENERATING STATION

8.02 The Bowline Point Generating Station occupies a 245-acre tract, which includes the 53-acre Bowline Pond and 11-acre Bowline Point public recreational facility. A short corridor (3.4 miles) links the station to transmission facilities that existed prior to the construction of the power plant.

8.03 Areas were drained and filled in preparing the site for the project. More extensive portions of the site were cleared of vegetation and refuse and graded. Construction work on structures, roads, access facilities, parking lots and other paved surfaces and landscaping has been completed. Development of the site entailed the loss of an estimated 60 acres of wetlands and a loss of habitat for upland species not adapted to a mix of urban, surburban and industrial conditions.

8.04 The station structures and equipment represent a permanent commitment of construction materials, such as cement, sand, gravel, lumber, masonry, structural steel and steel siding, and a wide variety of manufactured items ranging from boilers, turbine generators, pumps and other large components to valves and plumbing supplies. Although a portion of the commitment may be salvageable and reusable on decommissioning the station, the major part is irretrievably committed.

8.05 Operation of the Bowline Point station at full power entails the consumption of fuel oil at the rate of 1,897 barrels per hour. The corresponding annual consumption is approximately 10 million barrels at a load factor of 0.66. Water losses due to the rejection of waste heat are about 30 cubic feet per second. The installation of closed cycle cooling would increase the evaporative loss of water by 10 cubic feet per second. Minor quantities of expendable material supplies, such as chemical compounds used in water treatment and equipment cleaning, maintenance supplies, detergents and sanitary products are consumed each year.

8.06 The withdrawal of water from the Hudson River for condenser cooling and other purposes gives rise to the destruction of fish and other aquatic organisms through entrainment and impingement. The continued destruction of striped bass and other species by the Bowline Point and other existing stations would lead to a reduction in the adult standing stock in the Hudson River.

8.07 The term irreversible (or permanent) as applied to the effect of entrainment or impingement on a population of striped bass has the ecological connotations of: (1) bioligical extinction (no striped bass of any age class in the Hudson River for all time), (2) fishery extinction (such small striped bass population spawning in the Hudson River as to be insignificant in its contribution to the sport and commercial striped bass fishery for all time), or (3) permanent reduction (but above the fishery-extinction level) in population size which continued after the stress is removed.

8.08 Biological or fishery extinction due to entrainment and impingement of striped bass eggs, larvae, and juveniles is only a remote possibility, even with once-through cooling at all power plants on the Hudson River. Factors preventing extinction may include the occurrence of occasional strong year classes that could possibly offset several years of power plant impact. Recruitment of spawning fish from other Atlantic coastal stocks is also possible, although the extent of its potential occurrence is presently unknown.

8.09 A permanent reduction in the striped bass population size is ecologically possible. If one component of a biological community is selectively stressed so that the population is reduced to low levels for many years, a permanent change may occur in the structure of the system of which the species is a part and the population may be unable to return to the original size after the stress is removed. However, the possibility of causing an irreversible change in the population of striped bass is not presently considered as a matter of primary concern.

8.10 Any reduction in the stock size of striped bass or other species resulting from the power generation activities on the Hudson River must be considered an irretrievable commitment of that biological resource for the period over which the reduction remains in effect. The fishery yield lost during the period of reduced stock level would also be irretrievable.

COMMITMENTS AT THE ROSETON GENERATING STATION

8.11 The Roseton Generating Station occupies a 133-acre tract of land. A small pond on the site, previously used for fly ash disposal, has been filled in developing the site. No wetlands have been affected by the construction of the station.

8.12 The commitment of materials, energy and labor in constructing the Roseton station is similar to that described previously in connection with the Bowline Point station. Operation of the Roseton station involves the consumption of approximately 12 million barrels of fuel oil per year. Evaporative losses of cooling water presently amount to an estimated 35 cubic feet per second and would increase to 42 cubic feet per second if an evaporative closed cycle cooling system is installed.

8.13 Impacts on the aquatic ecosystem of the Hudson River estuary resulting from the operation of Roseton station are similar in nature, if not in degree, to those associated with the Bowline Point station. As mentioned previously, the continued operation of these two stations in combination with other existing facilities on the river might lead to irreversible changes in the ecosystem. There is substantial doubt, however, that this event is likely to cocur.

CHAPTER 9

COORDINATION WITH OTHERS AND COMMENTS AND RESPONSES

PUBLIC PREPARATION

9.01 In preparing the Draft Environmental Impact Statement, the District contacted a large number of Federal, state and local governmental agencies, institutions, commissions, societies and corporations, with the primary objective of including all important studies and elements of information in the development of the statement. Additionally, the District obtained literature searches on topics pertinent to the generation of electrical energy on the Hudson River from the National Technical Information Service (U.S. Department of Commerce, 1976c) and the Atomic Industrial Form (Atomic Industrial Forum, 1976), and the Smithsonian Science Information Exchange, Inc. (Smithsonian, 1976).

9.02 The District informed the U.S. Environmental Protection Agency, Region II and the U.S. Department of the Interior, Northeast Region of its obligation relating to the Bowline Point Generating Station and the Roseton Generating Station by letters dated, respectively, 15 and 16 November, 1976 (Appendix B). Contact was made with the U.S. Federal Power Commission, Bureau of Power and the Acting Regional Engineer, New York Regional Office to identify sources of information pertaining to the need for electrical power in the State of New York and other matters that might involve the Hudson River. Information on wildlife, fish and fisheries was requested from the U.S. Department of the Interior, Fish and Wildlife Service and the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

9.03 Several officials were contacted in the New York State Executive Department, Office of Parks and Recreation; the Department of State, Division of State Planning; the Department of Public Service, Public Service Commission; and the Department of Environmental Conservation, Division of Air Resources, Division of Fish and Wildlife and Division of Pure Waters. Information on land use was obtained from the appropriate New York State offices, the planning departments of most of the counties within the study area and the Tri-State Regional Planning Commission. Socioeconomic data pertaining to localities of interest were obtained from officials in county and township governments.

9.04 Informed individuals at a number of universities, institutes and public associations, including New York University, Cornell University, Dutchess County College, Boyce Thompson Institute, Natural Resources Defense Council, Regional Plan Association and Mid-Hudson Pattern for Progress, Inc. were contacted. Field data and other pertinent information were requested and obtained from Utility companies that operate power plants on the Hudson River, namely, Orange and Rockland, Consolidated Edison, Central Hudson and Niagara Mohawk and from the New York Power Pool.

GOVERNMENTAL AGENCIES

9.05 Comments on the Draft Environmental Statement were received from the following governmental agencies:

Federal Agencies

Department of Agriculture, Forest Service
Department of Agriculture, Soil Conservation Service
Department of Commerce, Assistant Secretary for Science and Technology
Environmental Protection Agency, Region II
Department of Health, Education and Welfare, Office of the Secretary
Department of Health, Education and Welfare, Region II
Department of Housing and Urban Development, Area Office
Department of the Interior, Office of the Secretary
Department of Transportation, Federal Highway Administration
Department of Transportation, Regional Representative of the Secretary

State of New York

Department of Environmental Conservation
Department of Law
Metropolitan Transportation Authority

CITIZEN AND OTHER GROUPS

Comments were received from the following groups:

Utilities

Central Hudson Gas and Electric Corporation
Consolidated Edison Company of New York, Inc.
Orange and Rockland Utilities, Inc.

Other Parties

National Audubon Society
Natural Resources Defense Council, Inc. on behalf of the Hudson River Fisherman's Association
Save Our Stripers, Inc.

LETTERS OF COMMENT

9.06 All letters of comment received on the Draft Environmental Impact Statement are reproduced in Appendix A. Comments to which responses have been prepared in the Final Environmental Impact Statement are indicated in the margin of each letter. Each letter is numbered and comments are numbered consecutively within each letter. Responses to these comments are given in Chapter 10.

CHANGES TO THE DRAFT ENVIRONMENTAL IMPACT STATEMENT

9.07 Comments received on the Draft Environmental Impact Statement and new data that have become available since the Statement was issued, have resulted in revisions to several sections of the Statement. The availability of new data and technical testimony submitted as part of the on-going adjudicatory hearings among the Utilities and the U.S. Environmental Protection Agency have resulted in extensive revisions to the impact analyses of entrainment, impingement, and long-term reduction in adult fish populations in Chapter 4. Additionally, the computer analysis of the thermal impact of cooling water discharges was expanded to include a simulation of conditions that could result during a drought year. Corrections were also made to the input conditions of the computer analysis of salt drift from cooling towers and the results computed on a monthly rather than a yearly basis. A drought year was also included in the analysis of salt drift. In Chapter 6 (Alternative Actions), more cooling alternatives have been discussed and a section on potential improvements to intake structures has been added. Other changes to the text resulting from responses to comments did not materially change the findings as originally presented. These text changes are noted in response to comments given below.

RESPONSE TO COMMENTS RECEIVED ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT

9.08 Responses to the letters of comment on the Draft Environmental Impact Statement reproduced in Appendix A are given below. Each comment to which a response has been prepared is indicated by a vertical line in the margin of the letter in Appendix A. Each letter has been given a number and comments within each letter have been numbered consecutively so that every comment has a unique hyphenated number that identifies it as to the letter it is from and which comment it is within the letter. For example, Comment 14-23 would be comment 23 from letter 14.

9.09 The response is given immediately below the comment. In some cases, the original comment has been summarized, paraphrased or shortened for inclusion here. In such cases, the reader may check the original letter in Appendix A for the full text of the comment.

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE

Comment 1-1

Continued operaiton of Bowline Point Station would have no significant effect on forested land, beyond that referred to in our comments of 1973.

Response

Since the chronic effects of salt drift to vegetation are unknown, and the potential acute, visible impacts can be assessed only for less than 5 percent of the species occurring in the South Mountain-High Tor State Park Forest, a determination of "significant effect on forest land" would be prelimiary at best (see paragraph 4).

Comment 1-2

Direct damage to plants from salt would be temporary as stated in paragraph 4.82, pp. 4-47 and 4-48 of the DES. If soil salt content should approach the threshold of damage for dogwood and other sensitive tree species, more resistent species could be substituted.

Response

A generalization that salt drift damage would be temporary is not justified due to the paucity of drift experiments (see paragraph 4). Replacing damaged residential and urban ornamentals with resistant forms would be feasible. An attempt to substitute salt-drift resistant species in natural ecosystems would probably result in greater environmental impacts from physical disturbances, such as trampling and rooting, than if natural recolonization of affected sites were allowed.

U.S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, NATIONAL MARINE FISHERIES SERVICE

Comment 4-1

We recommend that the Corps of Engineers consider the alternative in which the present permit be modified to follow the major stipulation found in the National Pollution Discharge Elimination System permit issued by the U.S. Enviornmental Protection Agency.

Response

The alternative of closed cycle cooling is one of the alternatives included in the EIS, and will be considered by the Corps in any subsequent actions which may be taken with respect to modification, suspension or revocation of the outstanding permits.

U.S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, ENVIRONMENTAL RESEARCH LABORATORIES.

Comment 5-1

Although the report summary concludes from monitoring data that in no instance were the air quality standards exceeded, a numerical simulation discussed in Section 4.54 showed 24-hr average SO_2 concentrations would exceed standards on the High Tor ridge line near the plant. Furthermore, attempts to monitor the ridge location produced inconclusive results because of the apparent sporadic nature of the monitoring and tracer test program. In fact, the report goes on to say in Section 4.56 that the possiblity of exceeding SO_2 standards could not be ruled out on the basis of the surveys. The implication in the summary of adverse environmental impacts (page iv) is otherwise.

Response

The conclusion reached in paragraph 4.56 of the DES is based on a partial analysis of available information. A complete analysis leads to the conclusion now set forth in the FES, namely, that, on the basis of both observations and consideration of meteorological records, the possiblity of contact between the plume and the High Tor ridge is remote.

U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION II

Comment 6-1

The EPA recommends that a final EIS not be issued until EPA's adjudicatory hearings are ended and a decision on the closed-cycle requirement is rendered.

Response

The Corps is preparing the EIS pursuant to the time requirements of a court approved schedule which is embodied in the Final Order. The court, in establishing its deadline, was aware of the ongoing EPA hearings dealing with closed cycle cooling, then in progress but did not link the Corps' obligation to file its final EIS on the progress or completion of those hearings. The recommendation contained in these comments is therefore in conflict with the Final Court Order, which imposes on the Corps a time limit with respect to filing the Final EIS. It should be noted, however, that the EIS has included in its discussion of the alternative of closed cycle cooling all information and data developed to data in the on-going EPA adjudicatory hearings dealing with this subject.

Comment 6-2

Air quality data and modeling results indicate that the source does not violate the National Ambient Air Quality Standards.

Response

Comment noted.

Comment 6-3

In light of these comments and in accordance with EPA Procedure, we have classified this draft EIS as ER-1, indicating environmental reservations on the undisclosed Corps proposal (ER) and information sufficient for each a determination (1).

Response

Comment noted.

U.S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE, OFFICE OF THE SECRETARY

Comment 7-1

We noted that the impact on the quality of river water as related to the marine life is addressed, including maintenance of water quality (SB) level necessary to permit swimming. However, it is also noted that there is a need for upgrading the existing quality level to provide a potential backup potable water source. The effect on this potential source from the discharge of boiler blowdown and other chemicals should be addressed.

Response

As indicated in paragraph 2.33 of the DES, water quality over the portion of the Hudson River estuary roughly between mile points 30 and 60 is generally good (Classes SB and B) but unsuitable for municipal water supply because of the intrusion of saline water. Both the Bowline Point and Roseton stations are on this section of the estuary. Attention to the Hudson River as a potential source of water for the regional supply system has, to date, focused on the reach of the estuary between mile points 86 and 95 (paragraph 1.103 of the DES). Beyond the consideration of the remoteness and downstream location of these power plants from the possible source of potable water, it may be well to note that the release of contaminants from the power plants in quantities meeting limitations imposed through the National Pollutant Discharge Elimination System permit is not expected to cause any appreciable degradation in the quality of the receiving waters (paragraphs 4.40, 4.44, and 4.47 of the DES).

Comment 7-2

The emissions from the power plant (or plants) are addresssed in terms of both the local effect and the additive effect on the quality of the air shed. Analysis of the impact on human health would be essential in order to complete the assessment.

Response

The impacts that the Bowline Point and other generating stations on the Hudson River exert on the quality of the air shed are analyzed in terms of compliance with or possible violations of regulatory standards. These standards, of course, are set on the basis of public safety and welfare so that further considerations of human health, particularly where all applicable standards are being met, appears to be beyond the scope of the environmental statement.

Comment 7-3

The entrance into the food chain (sport fish) of the chemicals resulting from power plant operation and their potential for biomagnification needs analyses and assessment.

Response

The chemicals that may be discharged into the aquatic environment as a result of power plant operations are described in Table 4-1 and Appendix D.3-D.5. Most of these compounds are various acids and bases used for cleaning and preventing corrosion of equipment and would not be expected to bioaccumulate in aquatic organisms. Only one heavy metal, chromium in sodium dichromate ($Na_2Cr_2O_7$), is known to be present among these chemicals. Although some aquatic organisms may bioaccumulate chromium from low concentrations in the ambient environment, chromium has not been reported to biomagnify sequentially through the food chain. For several of the chemicals used, the composition is unknown and proprietary to the developing company (e.g., Drew Gard-100, Vertan). Those proprietary chemicals containing any of 129 Federally designated "priority pollutants" are undergoing evaluation by the U.S. Environmental Protection Agency (U.S. Environmental Protection Agency, 1979).

Comment 7-4

In summary, the potential for impacting public health and safety should be addressed in order to complete the statement.

Response

Public health is the primary focus of the District's analysis of the effect of the Bowline Point and the other generating stations on air quality and water quality in the study area. Public safety is considered specifically in paragraphs 4.229 and 4.230 of the DES in terms of potential accidents at the Bowline Point stations and in the transportation of fuel to the station.

U.S. DEPARTMENT OF THE INTERIOR, OFFICE OF THE SECRETARY

Comment 10-1

Several undocumented assertions occur in the draft statement. For exmaple, on page 4-10, it is stated that "In terms of the flow regime of the lower Hudson River, the evaporative losses of water caused by the rejection of waste heat from existing power plants are considered to be negligible." Such statements should be fully referenced and supported since we question that it can be properly concluded that these effects are negligible.

Response

Consumptive use of water associated with the rejection of waste heat from all of the existing power plants on the Hudson River estuary is estimated by the District to be of the order of 70 cubic feet per second (paragraph 4.24 of the DES). This estimate is based on duly referenced information supplied by the U.S. Environmental

Protection Agency, generally applicable rules-of-thumb taken as assumptions in the DES and well established physical constants. A comparison is next made between a consumption of 70 cubic feet per second, considered by the District to be a high or upper estimate and an average annual flow of 13,000 cubic feet per second gaged at Green Island, upstream of all the power plants under consideration. Considering further that the freshwater flow is augmented by an unknown amount supplied by three major tributaries downstream of the confluence of the Hudson and Mohawk Rivers--identified by the U.S. Department of the Interior as the Wallkill River and Kinderhook and Rondout Creeks (paragraph 2.25 of the DES)--the District concludes that the evaporative losses of water are negligible in terms of the flow required of the lower Hudson River.

In terms of depleting the freshwater resource, the District notes in its analysis that the major portion of the installed capacity on the Hudson River is on a reach considered unsuitable for municipal water supply because of the intrusion of saline water.

Comment 10-2

In several places in the draft statement, for example, paragraphs 4.180 to 4.183, the staff concludes that more accurate and reliable assessments of potential impacts might be possible if additional data were collected. Any request for additional studies should be predicated on an extreme need for specific types of information and a high probability of obtaining that information.

Response

Comment noted.

Comment 10-3

The Corps' acknowledgement on page 4-63 that 1974 was characterized by "exceptionally low freshwater flow" in the Hudson River introduces considerable reason for concern. Entrainment and impingement analyses for Bowline rely heavily on field data collected in 1974. Those data serve as input for very important model runs which may serve to identify alternate decision options. Basic questions regarding the representative nature of 1974 data and its incorporation into 40-year predictive models should be addressed.

The above statement on low flow could be correlated with the statement at the top of page 4-5 indicating that 1974 is "a year considered to be typical." Similarly, the table of Hudson River flows on page 2-15 should be correlated with the statement on page 4-63 concerning low freshwater flows.

Response

Comment 10-4

The draft statement on page 4-70, concludes that yolk-sac larvae of the Atlantic tomcod are most numerous downriver of Haverstraw Bay and, therefore, that this distribution greatly reduces their entrainment at Bowline. An equally credible conclusion is that the observed distribution, with a general downriver maximum density, is a direct result of entrainment and impingement at upriver power plants. The consequences of this alternative interpretation of existing data should be explored thoroughly in the final environmental statement.

Response

This statement has been deleted from the FES.

Comment 10-5

There is no evidence that the use of a Ricker-type function is valid in estimating long-term impacts to white perch, Atlantic cod-tomcod, and American shad. This largely invalidates any conclusions obtained by use of equilibrium reduction equation, regardless of the confidence with which impingement and entrainment losses might be estimated.

Response

A discussion of the use of the Ricker formulation to describe the population dynamics of Hudson River fish populations begins at paragraph 4.229.

Comment 10-6

For purposes of estimating entrainment mortality at Bowline and other power plants along the Hudson, the Corps selected intake f-factors (f_1) of 0.5 and 1.0. The rationale for using 0.5 and 1.0 is unclear. The final statement should include analyses and discussions of model predictions (percent reductions in adult stocks) based on values of 2.0, 5.0, and 10.0.

Response

The model used in the DES by Oak Ridge National Laboratory to estimate long term reduction in the adult striped population is not used in the FES.

Comment 10-7

The implicit conclusion from the discussion on page 4-70 and 4-71 of the dES is that blueback herring and alewife will sustain only slight entrainment losses because they spawn north of the river's power plants is suspect. The conclusion is dependent on the mistaken assumption that early life stages of blueback herring and alewife are distributed very similarly to American shad. This is not true. In fact, herring and alewife are more abundant in downstream areas as opposed to shad which occur in greatest numbers farther north. See Lawler, Matusky and Shelly (1977a, 1977b). The erroneous conclusions presented in paragraphs 4.159, 4.160, and 4.175 of the DES must be considered in light of these recent references.

Response

These sections have been eliminated from the DES and replaced with more recent information in the FES.

Comment 10-8

The draft statement on page 4-88 summarizes the utility companies' position concerning density-dependent growth, namely that there exists "...a significant negative linear correlation relating young-of-the-year density and growth for striped bass in the Indian Point region." This is inaccurate. A more recent report submitted by the companies points out that data presently available do not substantiate the relationship postulated earlier.

Response

More recent analyses by the Utilities have found a significant negative correlation between striped bass young-of-the-year population size and growth rate. Review of these data by the staff of the U.S. Environmental Protection Agency and their consultants indicates that this relationship cannot be substantiated. A discussion of this issue begins at paragraph 4.212.

Comment 10-9

The draft statement uses an estimate of striped bass mortality at the proposed Cornwall plant. This estimate is in error.

Response

Because of the uncertainty of implementation of the Cornwall project, its potential impacts are not considered in the FES.

Comment 10-10

Other than general statements about the species composition, relative densities and seasonal changes in Bowline Pond, the draft statement provides little useful information to describe fish populations.

Response

All presently available data on fish eggs and larvae in Bowline Pond has been summarized in the FES (Paragraphs 2.95 and 4.124). References to pertinent site-specific studies are provided if more details are desired.

Comment 10-11

There is general agreement that some adverse impacts, particularly those to striped bass, are regional--not localized. The precise geographic and numerical bounds of those impacts remain points of controversy. Nonetheless, relative to the discussion on page 4-1, it is important that the Corps of Engineers recognize the significance of the regional impacts of the Bowline plant and not rely solely on an assessment of cumulative power plant impacts to address regional concerns.

Response

A note has been added to paragraph 4.01 of the FES to indicate that, where appropriate, the analysis encompasses potential impacts of a regional character experienced beyond the limits of the study area.

Comment 10-12

The treatment on page 4-103 in the DES of the contribution of Hudson River striped bass to the Atlantic coastal population is vague and brief. The "contribution" issue deserves more thorough treatment in the final environmental statement.

Response

The issue concerning contribution of Hudson River striped bass to the Atlantic fishery is discussed in more detail in the FES, paragraphs 2 and 4, and Appendix D.

Comment 10-13

The assertion on page 3-6 of the draft statement, that the existing Bowline facility represents a "baseline or initial condition for future planning," requires further explanation. In our view, it fails to recognize the intent of Congress when it passed Public Law 92-500. We believe that the Federal Water Pollution Control Act Amendments of 1972 do not provide for, a priori, facilities such as Bowline as necessary contributors to water pollution. To the contrary, several sections of that Act, most notably 316(a) and 316(b) were intended to discourage such assumptions.

Response

This statement, contained in paragraph 3.23 of the DES, does not add substantively to the understanding of the relationship between the Bowline Point generating station and land use planning on the Hudson River estuary. It has been deleted.

Comment 10-14

The conclusion that Bowline Point Generating Station is not likely "to present an unusual constraint in devising plans to guide and control further growth" requires clarification. If the facility is permitted to operate with once-through cooling, it may very well influence future development along the Hudson River. Simply on the basis of water withdrawals and accompanying aquatic impacts, operation with closed-cycle cooling is preferred to once-through cooling. Closed-cycle cooling requires only 2 to 5 percent of the water used in once-through systems. A similar reduction in aquatic impacts could very easily influence future uses of the Hudson River Estuary.

Response

This statement contained in paragraphs 3.23 of the DES does not add substantively to the understanding of the relationship between the Bowline Point station and land use planning on the Hudson River estuary. It has been deleted.

Comment 10-15

We are pleased to note that the draft environmental statement, on page 3-3, recognizes the work proceeding under the current Hudson River Basin Level B Study. Any further studies or project implementation phases should be related to the findings of the basin-wide study.

Response

Comment noted.

Comment 10-16

The discussions in paragraph 4.85, on page 4-48 of the DES has not demonstrated that plants are more likely to be adversely impacted by average annual concentrations of salt in the air and rates of deposition of salt than by concentrations and depositions of greater magnitude and shorter duration. The entire discussion and analysis of potential impacts from salt depositionis keyed to average annual predictions. The usefulness of such an approach is questionable in the absence of more specific information concerning lethal exposure thresholds, acclimation capabilities, and duration-magnitude projections. The final statement should be expanded to cover these additional considerations.

Response

The DEIS discussions in paragraph 4.85 have been revised using the only reliable information available (see paragraphs 4.84 and 4.101). Lethal exposure thresholds and acclimation capabilities are not known, and duration magnitude projections cannot be made. The limitations of the salt drift impact assessment in the FEIS are explicitly stated in paragraph 4.86 .

Comment 10-17

Sections 2.123 and 2.124 on page 2-67 of the draft statement provide only scant information concerning existing recreational resources of the area under study. The basic listing of activities presented should be complemented by identifying some of the major attractions or by tabulating the total overall activities. For example, the total number of boat slips and boat ramps within view of the plant sites under study should be tabulated as should the total number of marinas and river access points near the plant sites. Major marinas or access points should be identified. The area could be overflown on randomly selected days to count the recreational vessels on the river to obtain estimates of boating use.

Response

Since the Bowline Point Generating Station is built and has been in operation for a number of years, its visibility is taken as the major source of potential impact on recreational facilities in the vicinity of the station. Considerable attention is given in the DES to the visual intrusion of the power plant (for example, paragraphs 4.220 through 4.224 and 5.02 of the DES) and the emphasis placed on its visual impact by the Hudson River Valley Commission in reviewing the Bowline Point project (paragraphs 1.57 and 3.18 of the DES).

From its analysis, the District has concluded that the visibility of the power plant and other aspects of the plant's operation relating directly to the human resources of the study area (paragraphs 4.216 through 4.236 of the DES) have not discernibly affected local land use, property values in the area of patterns of urbanization, industrialization and business activities (paragraphs 3.06 and 3.11 of the DES). Further, the public recreational facility provided in part by Orange and Rockland has proved to be a popular local attraction in spite of its close proximity to the power plant (paragraphs 1.43 and 3.07 of the DES).

For these reasons, the District does not consider the visual impact of the Bowline Point stations, in terms of its effects on local recreational amenities, to be a matter of substantive concern. Accordingly, the effort needed to cataloge the recreational facilities within the viewshed of the power plant, to estimate the usage of these facilities, and next to attempt to make comparisons between the preconstruction and operational phases of the Bowline Point project appears to be unwarranted. The District does recognize that the visibility of the station may inhibit certain types of residential, commercial or recreational developments in its vicinity (paragraph 3.11 of the DES). It may be well to note here that none of the comments on the DES point to any significant adverse impact on recreational facilities experienced since the construction of the Bowline Point station.

Comment 10-18

Swimming areas and camping areas within view of the plant sites should be identified with a measurement of acreage and river frontage. State parks in the area should be identified with data concerning acreage, annual visitation, shore frontage, distance to plant sites, vista intrusion, types of activities included. Valley resorts and clubs impacted by the visual intrusion on recreation sites with and without natural draft cooling towers and discuss the extent to which these effects might be mitigated by alternative cooling systems such as mechanical draft towers or a cooling pond.

Response

See response to preceding comment.

Comment 10-19

The protection of cultural resources has received only limited attention in the draft statement. We are particularly concerned about the possible impacts on three National Historic Landmarks shown on Table 2-16; they are: The Stony Point Battlefield, the Palisades Interstate Park and the Van Cortlandt Manor. In performing a more detailed analysis of impacts on these three historic sites, the State Historic Preservation Officer should be consulted along with local historical authorities, concerning the probability, character, and magnitude of impacts on all the sites identified. As indicated in paragraph 2.121, compliance with 36 CFR Part 800 appears to be warranted for at least three sites mentioned above. Further consultation with the State Historic Preservation Officer should confirm this.

Response

In the analysis presented in the DES, two potential sources of impact on historical resources are considered--acidic mists formed by the interaction of plumes from the stacks and cooling towers, if these are ultimately installed, and visual intrusion. On the basis of observations at operating natural draft cooling towers, the possibility of an increase in the incidence of fog and by inference, acidic mists, if these are formed at all, at ground level near the Bowline Point station is considered to be remote (paragraph 6.25 of the DES). Accordingly, it is not expected that damage to structures, including those of historical value, caused by corrosive airborne contaminants would be appreciably aggravated if evaporative cooling towers are installed. It may be well to note that recognition is given in the analysis to the contribution of the Bowline Point and Roseton generating stations to the formation of sulfate and nitrate aerosols and the attendant hazards of acid precipitation in the northern United States (paragraph 5.05 of the DES). Although the operation of these stations leads to no violations of applicable air quality standards.

Regarding the visibility of the power plants, the District has recognized the criterion of visual intrusion as one of the set of criteria identified by the U.S. Department of the Interior as pertinent in the determination of impact on historical resources (paragraphs 4.235 of the DES). Available analytical techniques to make such determinations, however, are limited and generally apply in predictive situations. In the case of the existing Bowline Point and Roseton generating stations, the District considers the revocation of its permits, forcing the abandonment and dismantling of the stations, as the only effective means of reducing possible visual impacts on historic sites in the vicinity of the stations. As stated in paragraph 6.01 of the DES, the District has considered this course of action and evidence of adverse impacts on historic sites is one of the factors entering into the District's final decision. No specific instance of damage to historic sites has been reported in comments to the DES.

Comment 10-20

Although there may have been previous ground disturbances in the area, we believe that the final statement should address the presence and protection as necessary, of archeological values that may be affected as a result of cooling tower construction. If these matters have not previously been considered at the proposed site of construction, they should be assessed at this time. The final statement should include the comments of the State Historic Preservation Officer and show compliance with 36 CFR Part 800.

Response

An archeological survey of the Bowline Point site has not been conducted. Accordingly, information needed to assess the potential for destroying archaeological values if cooling towers are constructed is not available to the District. The District has considered the requirement that an archaeological survey be conducted and that the necessary protection be provided as an additional condition to its permits covering the Bowline Point and Roseton Generating stations.

Comment 10-21

The discussion in paragraph 5.01, of adverse impacts on page 5-1 of the DES states that there is no reason to believe that the construction or operation of the Bowline and Roseton stations will affect groundwaters in their vicinity. We agree that the possibility of adverse impacts on groundwater are negligible since oil is being used as fuel. In the event of the conversion to coal, which appears to be unlikely, further analysis of groundwater impacts would be necessary. It is possible that the plant will be modified to use cooling towers under which conditions salt from the cooling tower drift may infiltrate the groundwater. The final statement should assess the potential for salt infiltration to the groundwater from this source.

Response

The maximum average deposition of salt at 0.2 mile of the proposed Bowline Point towers during the 1964-1965 drought would have been 39.5 kg/ha/yr (see paragraph 4.89). Salt deposition within 270 m of the ocean under a pine forest averaged 687.6 kg/ha/yr during a recent study (Potts, 1978). Because of this 17-fold difference and the presence of potable water at distances less than 270 m along oceanic coasts, the potential for adverse impact of salt to groundwater at Bowline Point is probably remote. The potential risk at Roseton is even lower due to substantially lower deposition rates than at Bowline Point (see paragraph 4.108).

STATE OF NEW YORK, DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Comment 13-1

To eliminate duplicative efforts, we suggest that the Army Corps of Engineers become a party to the on-going EPA adjudicatory hearings, or at least defer judgment on Bowline Point and other Hudson River power plants until EPA hearings have resolved the issue of close-cycle cooling.

Response

The Corps is preparing the EIS pursuant to the time requirements of a court approved schedule which is embodied in the Final Order. The court, in establishing its deadline, was aware of the ongoing EPA hearings dealing with closed cycle cooling, then in progress but did not link the Corps' obligation to file its final EIS on the progress or completion of those hearings. The recommendation contained in these comments is therefore in conflict with the Final Court Order, which imposes on the Corps a time limit with respect to filing the Final EIS. It should be noted, however, that the EIS has included in its discussion of the alternative of closed cycle cooling all information and data developed to data in the ongoing EPA adjudicatory hearings dealing with this subject.

Comment 13a-1

The consent decree directs the Corps of Engineers to prepare a draft EIS and circulate it for comments on the cumulative effects of Bowline Point Generating Station together with existing or proposed electric generating plants on the Hudson. A similar decree was issued for Roseton Generating Station. It is unclear whether the DES is designed to satisfy both decrees. The data for Bowline Point predominates, but discussion for the Roseton Plant also appear. We have reviewed the statement as pertaining to Bowline Point. It would be helpful to hear when a DES for Roseton is expected.

Response

The draft EIS was designed to consider the cumulative effects of existing or proposed electric generating stations on the Hudson River thereby satisfying the Consent Decrees issued for both Bowline Point and Roseton facilities. The decree issued for Roseton provided that the study and evaluation shall be based on information and data developed by the Corps or Engineers from the EIS prepared in connection with the operation of the Orange and Rockland plant at Bowline Point.

Comment 13a-2

The DES contains a clear explanation of the individual and cumulative thermal loads on the river due to once-through cooling. Yet the cumulative effects of other impacts such as noise, aesthetics, or salt drift from cooling towers are not consisely presented.

Response

Concern over the continued operation of the subject power plants with once-through cooling centers on their individual and combined effects on the aquatic ecosystem of the Hudson River estuary. Accordingly, this topic is prominent in the analysis presented in the DES.

Other potential sources of cumulative impacts, however, have not been overlooked. Among these are airborne-emissions of sulfur dioxide from the Bowline Point, Lovett, Roseton and Danskammer stations as well as possible interactions among the plumes from stacks and cooling towers, with the consequent formation of acidic mists. For reasons given in paragraphs 4.52 and 4.53 of the DES, the cumulative impacts of these stations on air quality in the study area are not expected to be appreciable.

There are presently no reported instances of citizens' complaints made as a result of noise generated at the power plants. Large structures such as power plants and cooling towers are at a rudimentary stage of development and means of deriving a succinct measure of cumulative visual impacts are not available. Such impacts are put into perspective in the DES by tracing the historic development of the Hudson River estuary (paragraphs 2.04 through 2.08) and relating the presence of the power plants on the river to that development (for example, paragraph 4.224 of the DES).

Comment 13a-3

Finally, the DES presents no recommended actions. There is no concluding summary which presents a preferred list of actions. The different alternative plans are not rated for their environmental impact. The reader receives no hint from the authors as to the solution which balances environmental impacts at Bowline Point. The Army Corps of Engineers has presented no proposal for Bowline Point Generating Station. A draft EIS should make some ordering of possible actions so that the reviewing agencies can best make comments to the Army Corps of Engineers. Therefore, the draft environmental statement should be redone incorporating the recommended actions and analysis supporting these recommendations. It should be reissued for comments after the Corps staff recommendations are incorporated into a draft statement, and after comments on this draft statement are received, a final environmental statement prepared and issued.

Response

The EIS was prepared to present several alternative actions related to the Corps of Engineers permit authorizing construction in navigable waters of the Hudson River of water intake structures forming part of the Bowline Point Generating Stations. Current regulations dealing with the preparation of the EIS do not require the Corps to rate the alternatives for their environmental impact. The data contained in the Final EIS will be utilized, however, by the Corps together with all other information contained in the administrative record in their decision affecting the modification, suspension or revocation of the existing permits.

what about upholding?

Comment 13a-4

The DES should compare the rate of flow in different parts of the intake train (Table 1-2) with the cruising speeds of fishes, such as Atlantic tomcod and striped bass, that are entrained and impinged at a high rate.

Response

The entrainment and impingement of striped bass and other fishes of the Hudson River are treated extensively in Chapter 4 of the DES. Noting the cruising speeds of these fishes and comparing these to the velocity of flow in various parts of the intake system is considered overly simplistic, possibly misleading and inappropriate in the section of the DES providing a description of the Bowline Point Generating station.

Comment 13a-5

The statement does not address the various methods by which these flow rates can be reduced to lessen impingement and entrainment losses during critical spawning or migration seasons.

Response

Such methods are discussed in detail in paragraphs 6.48 through 6.57 of the DES. An expanded section dealing with recent innovations in techniques designed to reduce damage at the water intakes of steam-electric power plants has been added to Chapter 6 of the FES.

Comment 13a-6

The construction of any of the cooling tower options, modifications of Bowline Pond inlet, dredging of Bowline Pond, or alterations of the intake or outflow will generate some amount of spoil. If a large volume of spoil is produced, then detailed evaluation of the impact of the disposal of the spoil is due including the location and ultimate disposition of the spoil. Additionally, the production of sediment during construction and its delivery in run-off to nearby water bodies should be addressed.

Response

Installing cooling towers at the Bowline Point station or implementing certain other alternatives to the present open cycle cooling systems would entail excavation work or dredging. Spoil would be generated in these operations and appropriate sites, either upland or at sea, would be needed for its disposal.

Comment 13a-7

Plants which will be subject to foliar injury from salt drift are not limited to the Orange and Rockland property as implied in the subsection of the DES beginning on pages 4-47, paragraph 4.80. Several critical areas will be exposed to increased airborne salt in the Hudson River Valley such as High Tor Mountain, Bear Mountain Park, and Harriman Park. A map and a more detailed description of the vegetation and critical areas potentially impacted by salt drift are needed.

Response

Only 11 plant species have been tested reliably for salt drift impacts. The distribution of these species and their potential to be damaged are discussed in paragraphs 4.85. The probability of other species being affected cannot be assessed due to a lack of information.

Comment 13a-8

In Section 2.81 of the DES, the discussion of effects on two species, the short-nose sturgeon (endangered) and the Atlantic sturgeon (threatened) is inadequate. Spawning and nursery areas are not mapped or described. Although this information is, in part, unknown, the DES does not hypothesize the likelihood of impact on these two important fish species.

Response

The existing populations of the two species of sturgeon are described in paragraph 2.81 (Endangered or Threatened Species) and the apparent effects of Hudson River power plants on sturgeon are addressed in paragraph 4. (impacts to Endangered or Threatened Species). These discussions have been expanded to include information in the testimony of W. Dovel (1979), which recently became available.

Comment 13a-9

Plants in the area are only identified and listed in paragraph 2.82, page 2-48 of the DES; no analysis on site or in the salt drift area appears. Experiments have shown Dogwood, a protected plant, to be a susceptible species to salt drift. Other protected plants may also be susceptible to salt drift.

Response

The salt drift impact assessment in the FEIS is the result of a site reconnaissance, literature critique, and computerized modeling of salt drift deposition. See paragraph 4.90 for specific species effects.

Comment 13a-10

The discussion of the physiography of the locale of the Bowline Point station contains no mention of the Ramapo Fault. The discussion should include some consideration of this feature.

Response

A reference to the Ramapo Fault has been added to discussion in paragraph 2.17. A more detailed discussion of this fault system may be found in Aggarwal and Sykes (1978).

Comment 13a-11

The probability of drought over the life of Bowline Point Generating Station is not addressed. Such climatological information is important in assessing possible impacts from salt drift.

Response

An analysis of salt drift during a drought year has been included in the FES.

Comment 13a-12

The oscillation of the salt wedge movement should be related to the likely increase in airborne salt in drift from the cooling towers.

Response

An expanded analysis of the salt drift including monthly variations in the deposition rate of salt, has been added to the FES.

Comment 13a-13

Discussions of adults, eggs, and larvae of the several species of fish occurring in Bowline Pond should include a comparison with fish in the open river and a record of abundance for a representative one-year period.

Response

The discussion of fish eggs, adults, and larvae in Bowline Pond and the Hudson River has been expanded in the FES and references provided for more detailed information.

Comment 13a-14

The data as presented in the thermal analysis and modeling section reflects sampling at specific times. A description which relates the frequency of occurrence of temperatures which exceed State and Federal standards would be helpful in understanding the expected thermal impact during the "worst case" situation.

Response

Additional information has been given in the revised analysis in the FEIS.

Comment 13a-15

The calculated total estimated loss of 70 cfs associated with the rejection of waste heat from all of the existing power plants on the Hudson River estuary, as discussed in paragraphs 4.23 through 4.26 of the DES, is indeed small when compared to 13,000 cfs, the average annual flow of the river at Green Island. However, the mean daily flow at Green Island drops to approximately 5,000 cfs during August in normal years and dropped to less than 3,000 cfs in August during the drought years of 1962-1964. Since Bowline Point is in an area of salt wedge dominance and draws brackish water most of the time, it is not expected to affect the movement of the salt wedge. However, the Roseton Plant may exert a greater influence, since it is further upstream. In addition, consideration should be given to the three proposed upstream stations, Greene County, Mid-Hudson, and Stuyvesant as well as to water withdrawn from the river by several municipalities, including the City of Poughkeepsie.

Response

As indicated in paragraph 4.24 of the DES, the District's estimate of the total loss of water due to the operation of existing power plants is considered to be an upper or conservative value. Further, flows gaged at Green Island represent the major portion but not the entire flow of freshwater into the Hudson River downstream of its confluence with the Mohawk River (paragraphs 2.25 through 2.28)

For these reasons, the estimated evaporative consumption of 70 cubic feet per second compared to an annual average flow of 13,000 cubic feet per second gaged at Green Island is expected to have a negligible effect in terms of the systematic, year-round movement of the salt wedge in the estuary. During years of normal or above normal flow, the salt front reaches the Bowline Point, Lovett and Indian Point stations at approximately mile point 40 in summer and fall, but does not reach the Roseton and Danskammer stations at approximately mile point 60 (paragraph 2.31 of the DES). During periods of abnormally low flow, the salt front moves to the Roseton and Danskammer stations and beyond, reaching as far as Hyde Park at approximately mile point 80 in the drought year of 1964. Thus, in normal years, an evaporative loss of freshwater amounting to 20 cubic feet per second due to the operation of the Roseton and Danskammer stations (paragraph 4.24 of the DES) might be compared to a flow of 5,000 cubic feet per second gaged at Green Island. In years of very low flow or severe drought, practically all of the estimated total evaporative loss of 70 cubic feet per second would be from brackish water. It is conceivable, however, that in intermediate situations the loss of 20 cubic feet of freshwater per second in the vicinity of the Roseton station could give rise to slight perturbations in the movement of the salt front.

With respect to possible future power plants on the river, the District recognizes that there would be a limit to the additional waste heat that could be accomodated without appreciably affecting the movement of the salt front or other hydrologic characteristics of the river or substantially depleting the freshwater resource (paragraph 4.26 of the DES). When this limit would be reached is unknown. Similarly, estimates of total withdrawals of water from the Hudson River by municipalities and industry is presently unknown. Regardless of whether or not these withdrawals have an appreciable effect on the movement of the salt front, it is clear that the added consumption of water caused by the operation of the power plants would make a small cumulative contribution to this effect for the reasons detailed above.

Comment 13a-16

Total settleable particulate deposition is presented on an annual basis in sections 4.49 through 4.72 of the DES. To be comparable with New York Ambient Air Quality Standards, monthly settleable particulate deposition should be presented.

Response

Reference is made in this comment to an extensive portion of the DES and it is difficult to pinpoint the specific instances in which annually-averaged deposition rates for settleable particulates are quoted in place of more useful values derived from averages taken over shorter intervals of time.

Comment 13a-17

Maximum predicted deposition for salt alone should have been presented for the critical months of July, August and September when river salinity is highest.

Response

A more extensive and detailed analysis of salt drift and the attendant deposition of salt is given in the FES. Monthly values of the deposition are given in the expanded analysis.

Comment 13a-18

It is stated in section 4.53 of the DES that merging of the cooling tower and stack plumes would occur frequently but no specific details of the orientations of the stack and proposed cooling towers with respect to the prevailing wind directions are given. Conflicting reports from plants with operating cooling towers exist with respect to increased acidity of rainfall or drift. While the authors do not expect this effect "to be appreciable," perhaps the degree of impact can be further refined.

Response

As stated in section 4.53 of the DES, knowledge of the physical and chemical phenomena leading to the formation of acidic mists in merged plumes is incomplete. There are, at present, no means of predicting either the frequency at which the plumes might interact or the extent and severity of the impacts associated with these interactions. Such potential effects are not expected to be appreciable in view of the paucity of evidence pointing to significant problems at fossil-fueled power plants equipped with evaporative cooling towers.

Comment 13a-19

The phenomenom of salt draft is treated in Sections 4.64 and 4.65 of the DES as a temporary condition that occurs only intermittently. Although the concentration of salt will vary, the exposure will be continual. Rain may provide some relief by rinsing the vegetation from external salt deposits. A 30 to 40 year exposure to salt-laden air may cause permanent changes in the vegetation. The final EIS should reflect this condition.

Response

An expanded analysis of salt drift and deposition is included in the FES.

Comment 13a-20

Maps of the Bowline Point and Roseton areas, with isoplethes to indicate salt concentrations and deposition rates, would assist in understanding how the analysis of salt drifts relates to the site. A map that translates the amount of salt deposition to the degree of expected damage to susceptable plant species would be helpful in assessing the adverse environmental impact of salt drift on vegetation.

Response

To the greatest extent possible, these suggestions are incorporated in the expanded analysis of salt drift presented in the FES.

Comment 13a-21

Requirements to replace specimens injured by salt drift (see page 4-47, paragraphs 4.81-4.85 of the DES) or plans for rinsing deposited salt off susceptible foliage should be discussed in the Final EIS.

Response

Replacement of injured species has been discussed for Comment 1-2. Rinsing deposited salt is theoretically possible but probably impractical since deposition on each plant would have to be continually monitored to determine when the no-visible-effect level would be attained.

Comment 13a-22

It may be more significant to analyze the impact of the Bowline and Roseton stations in relation to other Hudson River generating stations in the region. While the DES reviews such work, it draws no conclusions. The statement should note whether a course of action for Bowline Point and Roseton should be determined by analyzing the impact of each station individually or a comparison of all generating facilities within the region. It should also note whether an individual species analysis, as is presented for striped bass, is important in the analysis of impact. As this section stands, it is only a summary of literature, not a statement of analysis.

Response

The determination of a course of action concerning the Bowline and Roseton Generating Stations will be made based on impacts due to each station individually as well as the combined impacts of all power stations operating on the Hudson River. An environmental impact statement is an environmental disclosure document, the purpose of which is to contribute environmental information to the decision making process. An impact statement is not the decision document itself. Corps regulations specifically require that a course of action regarding permit applications cannot be announced until at least 30 days after release of the final environmental impact statement. The District disagrees with the statement that the DES is not an analysis of impacts.

Comment 13a-23

The section of the DES beginning on page 4-47, paragraphs 4.81-4.85 has a inadequate description of salt drift impacts. The air quality section (pp. 4-27 through 4-31) is not explicit in its estimation of the likelihood and location of salt deposition. An analysis of the expected impacts is not given in either section. Three susceptible species are listed; of these, flowering dogwood, is a protected native plant.

Response

The DEIS discussions have been replaced with the only reliable information available concerning salt drift effects (see paragraphs 4.102). Flowering dogwood probably would not be visibly, acutely affected during a drought such as 1964-5.

Comment 13a-24

Mitigation measures for foliage injured by salt drift are not discussed in the section of the DES beginning on page 4-47, paragraphs 4.81-4.85. The following issues should be addressed in the Final EIS:

- replacement costs for injured plants,
- agent responsible for plant replacement, and
- long-term impacts to vegetation.

Response

Since the potential effects of salt drift to plants can be assessed for only 11 species, an estimate of replacement costs would not be reliable. The designation of parties responsible for environmental damage costs is not a function of an environmental impact state. Long-term drift imapcts to vegetation are not known. (see paragraph 4.).

Comment 13a-25

On page 4-49, paragraph 4.88 of the DES, the statement summarizes that the cumulative impact on upland ecosystem from salt drift will be similar among the various Hudson River power plants. Furthermore, the statement indicates that, "the overall land area devoted to power plants would be a small percentage of the total land area of the Hudson River Valley." The authors oversimplify the situation.

Response

The DEIS discussion on page 4-47 has been deleted since cumulative salt drift impacts cannot be properly assessed due to a lack of sufficient information.

Comment 13a-26

Since impingement losses at Bowline are greatest between October and April, and coincide with the lowest thermal loads on the river, perhaps a scheme of reduced pumping would alleviate impingement losses. The statement does not seem to try and correlate the different impacts with respect to season or overall thermal conditions in the river.

Response

Problems associated with this alternative are discussed in Chapter 6 of the FES beginning at paragraph 6.69 .

Comment 13a-27

In the DES, paragraph 4.116, entitled Fish Impingement, the analyses relies heavily on impact to striped bass. An attempt to better assess the adverse impacts on other species should be made.

Response

The Bowline fish impingement section has been rewritten for the FES. The revised section discusses impacts to other species of fish including white perch, blueback herring, rainbow smelt, alewife, bay anchovy, and Atlantic tomcod.

Comment 13a-28

The alternatives to the present once-through cooling system are not presented in any detail. Natural draft cooling towers are described but a detailed comparison of relative impacts is lacking. The individual and cumulative effects of, for example, increased icing and fogging, increased and mortality, evaporative losses on river flow regime and blowdown discharges are not compared to the adverse impacts of once-through cooling. The alternatives to natural draft cooling towers are presented cursorily and, seemingly, without seriousness.

Response

As indicated in paragraph 1.61 of the DES, the U.S. Environmental Protection Agency is requiring, through the provisions of the National Pollutant Discharge Elimination System (NPDES) programs, that closed cycle-cooling systems be backfitted to the Bowline Point and to the other eligible power plants on the Hudson River. These requirements are being contest by the utility companies involved and an adjudicatory hearing on the matter is currently in progress before the Environmental Protection Agency. Decisions on whether and at which facilities closed-cycle cooling systems will be required, will be made by the Environmental Protection Agency.

Accordingly, the District has assessed the impacts associated with the Bowline Point and Roseton stations operating both with open-cycle and closed-cycle cooling systems as well as the cumulative impacts of closed-cycle cooling systems at all of the eligible plants on the Hudson River. This situation would prevail in the long term if the Environmental Protection Agency's present requirements ultimately remain in effect and if the District maintains its present permits and conditions relating to the subject power plants. A number of closed cycle cooling alternatives are considered in this context (paragraphs 6.10 through 6.64 of the DES) since decisions on the specific type of cooling system to be installed at each of the eligible power plants have not been made to date. The objective of this portion of the District's analysis is to emcompass the range of possible impacts associated with closed-cycle cooling and to focus on the pertinent characteristics of each alternative system that appears practical. In this manner, the District has considered the outcome of some of the alternative options relating to the continued operation of the Bowline Point and Roseton generating stations.

There is no intent on the part of the District to provide a detailed analysis on which to base the choice of a particular type of closed-cycle cooling system as best suited for the Bowline Point Station. Such an analysis would require information that has not been developed to date. Orange and Rockland has identified natural draft evaporative cooling towers as the preferred closed-cycle cooling alternative and have prepared technical design documents for a proposed system (Orange and Rockland, 1974a; 1977).

On the basis of this design, the District has made estimates of the environmental impacts that may be expected to result from the installation of a natural draft cooling system as well as comparisons of these impacts with the impacts associated with practical alternative systems (Chapters 4 and 6 of the DES and FES). Underlying this assessment and comparative analysis are general considerations and findings reported in the literature, generally applicable rules of thumb and parallels drawn, wherever appropriate, from an analysis related to cooling alternatives at Unit 2 of the Indian Point station (U.S. Nuclear Regulatory Commission, 1976). It may be anticipated that more detailed analyses on alternative cooling systems and their environmental impacts will be submitted by Orange and Rockland to the District when the company submits an application for the permits necessary to construct a closed-cycle cooling system. An environmental assessment of the various alternatives would be made at that time.

Comment 13a-29

A comparison of the icing and fogging of the cooling tower alternatives in the Bowline Point vicinity should be added to paragraphs 6.24 through 6.26 of the DES.

Response

Paragraphs 6.24 through 6.25 of the DES deal with the atmospheric effects associated with evaporative material draft cooling towers. Information is given in these paragraphs to support the District's conclusion that fogging and icing resulting from the operation of natural draft towers at the Bowline Point stations are not expected to pose any significant problem. In the case of mechanical draft cooling towers, it may be anticipated that the atmospheric effects resulting from the release of warm moist air relatively close to ground level would be more pronounced, as indicated in paragraphs 6.37 and 6.38 of the DES. On the basis of operating experience reported in the literature and an analysis of alternative closed-cycle cooling alternatives for Unit 2 of the Indian Point generating station (U.S. Nuclear Regulatory Commission, 1976). Light friable ice is expected to form in the vicinity of the cooling towers under certain meteorological conditions and in most instances, fogging and icing are expected to be confined to distances of 1,000 to 2,000 feet from the towers. Experience with spray cooling ponds is more limited. Drift generated by the spray modules is substantial and an application of this type of cooling system in Bowline Pond would require a careful design to avoid creating a problem in the residential neighborhoods close to the power plant. As indicated in paragraph 6.42 of the DES, the District estimates on the basis of available information that a buffer zone of 1,000 to 1,500 feet would be needed to confine fogging and drift from the spray cooling modules to the site.

Comment 13a-30

The cooling pond alternative (paragraphs 6.40 through 6.42 of the DES is routinely mentioned and dismissed without an explanation of why this alternative is not feasible. A more detailed discussion of this and other alternatives should be included.

Response

A cooling pond at the Bowline Point generating station is considered impractical because of the inordinate land requirements, estimated to by 750 acres (paragraph 6.40 of the DES). This requirement could be reduced by a factor of approximately 20 by the introduction of spray modules so that the existing Bowline Pond could, in principle, serve as a closed-cycle cooling system (paragraph 6.42). However, the several factors discussed in paragraphs 6.41 and 6.42 of the DES must be considered in greater detail before a final judgement can be made as to the practicality or advisability of installing spray modules in the Bowline Point.

As indicated in response to a previous comment, all of the alternatives discussed in the DES are considered on the basis of available information and in detail deemed sufficient in relation to the District's responsibilities under the National Environmental Policy Act.

Comment 13a-31

The proposed rescheduling of plant operation, discussed in paragraphs 6.48 through 6.57 of the DES, seems to be a legitimate proposal, regardless of the ultimate decision (regarding the need for a closed-cycle cooling system). The plant could be scheduled, in synchrony with others, so that entrainment and impingement losses are diminished during the construction of cooling tower, cooling pond, or other structural modifications which may be mandated. This concept has value and should be pursued during the interim period of construction. However, this alternative is presented superficially and without an assessment of its impact on feasibility.

Response

Various restrictions that might be imposed on the operation of the Bowline Point generating station are discussed in broad terms in paragraphs 6.48 through 6.57 of the DES. For reasons mentioned throughout this section, it is impossible without further analysis and information to determine the potential effectiveness of these restrictions with respect to the aquatic ecosystem of the Hudson River. As indicated in the DES, a modified schedule of operation of the Bowline Point station, possibly as part of a comprehensive management program within the New York Power Pool (paragraphs 6.61 and 6.62 of the DES) or in combination with other protective measures, may be an alternative to closed-cycle cooling that is deemed acceptable by the U.S. Environmental Protection Agency. If this is not the case, restrictions on the operation of the power plant may prove to be sufficiently attractive to warrant the imposition of such restrictions while a closed-cycle cooling system is under construction, or indeed, in operation. Careful consideration will be given by the District to the possibility of improving conditions related to the operation of the power plant at the time an application is made by Orange and Rockland to secure the permits necessary to construct a closed-cycle cooling system at the Bowline Point station.

Comment 13a-32

A variety of modifications to the intake structure are mentioned but not analyzed in paragraphs 6.58 through 6.60 of the DES. It is difficult to review these proposals without a description of the possible effects in minimizing losses or the feasibility of construction.

Response

An expanded section on possible improvements to the power plant intake structure is provided in the FES. Included in this discussion are several modifications that are considered to be technically feasible and projections that can soundly be made regarding their potential effectiveness. As stated in the DES, the District regards these modifications as alternatives to closed cycle-cooling, any one of which may prove to be acceptable to the U.S. Environmental Protection Agency.

Comment 13a-33

The above proposals in Section 6 may be valuable and realistic alternatives to once-through cooling or cooling towers. Yet, no in-depth analysis appears in the DES. The ultimate decision for the cooling system at Bowline Point must consider these alternatives. The incorporation of these methods may preclude the necessity of a cooling tower; thus, impingement and entrainment losses will be reduced without introducing folair damage from salt drift, increasing icing and fogging, noise pollution, aesthetic degredation, and addition consumptive water use which are coincident with cooling towers.

Response

Responses to previous comments elucidate the context in which the District has analyzed the possible alternatives to closed-cycle cooling.

Comment 13a-34

In a letter referred to on page B-5 of Appendix B-1, the Army Corps of Engineers recommended that Bowline Point Generating Station "be placed on a last-on, first-off method of operation to minimize the use of the plant during spawning seasons of striped bass." The authors should repeat this recommendation in its section on alternatives to cooling towers, instead of burying it in an appendix.

Response

The "last-on-first-off" mode of operation is described in paragraph 6.55 of the DES and considered together with other operational restrictions in paragraphs 6.48 through 6.57 of the DES.

Comment 13a-35

The comparison of capability losses and costs of two different cooling towers done by the utility is found in an appendix. Such a discussion should appear in Section 6, the section which deals with alternative actions, with a comment from the authors in regard to the realiability of such figures. This valuable information should not appear only as a reference in an appendix.

Response

An analysis of the monetary costs associated with a natural draft evaporative cooling system for the Bowline Point station is given in paragraphs 6.29 through 6.32 of the DES. Under present conditions of high energy costs, differences in the overall economics of natural and mechanical draft systems are expected to be marginal or slightly in favor of the natural draft systems. Differences in the loss of capability are small and result from an optimization in balancing capital costs against operation and maintenance costs.

STATE OF NEW YORK, METROPOLITAN TRANSPORTATION AUTHORITY

Comment 15-1

The Draft Environmental Statement appears to support the use of cooling towers as part of the condensor system. We would like to point out that there is considerable controversy about the overall effectiveness of such towers in reducing environmental impacts. In addition, there is no doubt that the energy efficiency of the power plant will be reduced by the use of the towers.

Response

The impact of salt drift from cooling towers at Bowline and Roseton is discussed in the FES beginning at paragraph 4.85 . The effect of cooling towers on power plant efficiency is discussed beginning at paragraph 6.18 .

CENTRAL HUDSON GAS AND ELECTRIC CORPORATION

Comment Letter 16

In this letter it is stated that:

- the Corps cannot alter the permit as presently in effect.
- the Draft Environmental Impact Statement exceeds the terms of the Consent Decree as it relates to the Roseton Generating Station.

Response

To the extent that the comments question the Corps' responsibility to prepare the EIS, the Final Order issued by the court mandates that the Final EIS be filed by a date certain. During the course of the litigation, arguments were made that the Corps should not be required to complete the EIS in view of the pendency of the EPA adjudicatory hearings. Notwithstanding, the Corps was ordered to proceed with and complete the filing of the Final EIS. To the extent that the comments suggest limiting the scope of the EIS, they are clearly inappropriate to current regulation and policy, which require the EIS to include a sufficiently broad discussion of connected actions, cumulative actions and similar actions. The discussion of alternatives should address the no-action alternative, other reasonable courses of actions and mitigation measures as well as impacts that may be direct, indirect or cumulative.

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

Comment 17-1

In the Draft Environmental Statement (DES) for Bowline, the Corps has considered four alternative actions, but has not yet selected one of them. We urge that the first contention of the present permit, be adopted. Selection of this option would essentially preserve two of the other options as well, since it recognizes that a final determination with respect to cooling systems, plant intakes, and operations of the Hudson River power plants will result from the current proceedings pursuant to the Federal Water Pollution Control Act (FWPCA).

Response

This comment relates to the ultimate action which may be taken by the Corps with respect to modification of the existing permit, and not to the preparation of the EIS. As such, the comment is noted.

Comment 17-2

Clearly, the Corps should avoid duplication of effort and leave to the agency authorized by the FWPCA the task of setting limitations applicable to the cooling water systems of the power plants in question. That agency will have the opportunity to consider and evaluate the voluminous record of ecological studies and analyses being produced in this case, and reach a reasoned decision on what remedial action, if any, need be taken. In adopting final determinations since proceedings pursuant to FWPCA are already underway, with testimony having been submitted by the utilities in July 1977, and hearings scheduled to start on December 6, 1977. Indeed we believe that Section 101(f) of FWPCA, if it means anything at all, means that the Corps should defer to the FWPCA proceedings in the circumstances of the Hudson River power plants.

Response

The Corps is preparing the EIS pursuant to a court approved schedule. The court, in approving the deadline, was aware of the ongoing EPA hearings on closed cycle cooling which were in progress or completion of those hearings. The recommendation contained in this comment, therefore, is in conflict with the Final Order, which imposes on the Corps a time limit with respect to filing the Final EIS. It should be noted that these hearings commended in 1977 and, at this point, are open-ended. It further should be noted that the EIS has included in its discussion of the alternative of closed cycle cooling all information developed to date from the ongoing EPA administrative hearings dealing with this subject.

Comment 17-3

We believe the Corps should defer to the FWPCA proceeding for the ultimate determination of the cooling system for Bowline. However, if the Corps intends to act on its own pursuant to NEPA, this DES is an inadequate basis for such action. No analysis of the relative costs and benefits of alternative actions, including various mitigating measures is presented. The Corps has not presented such an analysis, nor has it evern summarized the factors that must be weighed in this case or attempted a qualitative balancing.

Response

The Corps is required to utilize a systematic interdisciplinary approach which will ensure the integrated use of the natural and social sciences in planning and decision making. To this end the EIS has included a detailed discussion of the following:

1. The environmental impact of the proposed action.
2. Any adverse environmental effects which cannot be avoided should the proposal be implemented.
3. Alternatives to the proposed action.

4. The relationship between short term uses of man's environment and the maintenance and enhancement of long term productivity.

5. Any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

ORANGE AND ROCKLAND UTILITIES, INC.

Comment Letter 18

In this letter, the jurisdiction of Corps of Engineers to compel changes in operating conditions of any existing power plants on the Hudson River is questioned and that the alternatives available to the Corps is limited.

Response

To the extent that the comments question the Corps' responsibility to prepare the EIS, the Final Order issued by the court mandates that the Final EIS be filed by a date certain. During the course of the litigation, arguments were made that the Corps should not be required to complete the EIS in view of the pendency of the EPA adjudicatory hearings. Notwithstanding, the Corps was ordered to proceed with and complete the filing of the Final EIS. To the extent that the comments suggest limiting the scope of the EIS, they are clearly inapposite current regulations and policy, which require the EIS to include a sufficiently broad discussion of connected actions, cumulative actions and similar actions. The discussion of alternatives should address the no-action alternative other reasonable courses of actions and mitigation measures, as well as impacts that may be direct, indirect, or cumulative.

COMBINED TECHNICAL COMMENTS BY: CENTRAL HUDSON GAS AND ELECTRIC CORPORATION, CONSOLIDATED EDISON COMPANY OF NEW YORK, INC., ORANGE AND ROCKLAND UTILITIES, INC., AND THE POWER AUTHORITY OF THE STATE OF NEW YORK

Comment 19-1

Paragraph 1.07 of the DES does not indicate that the Calspan Corporation prepared a Draft Environmental Impact Statement which was submitted to the Council on Environmental Quality on August 23, 1974.

Response

A footnote to Paragraph 1.07 of the DES has been revised to show that a draft environmental statement relating to the Bowline Point Station was prepared and submitted to the Council on Environmental Quality on 23 August 1974.

Comment 19-2

A clear photograph showing the Bowline Plant and its relationship to its surroundings should be used in place of Figure 1-1.

Response

Figure 1-1 of the DES has been upgraded to show a clearer photograph of the Bowline Point Generating Station. An artist's impression providing an indication of the visual dominance of natural draft cooling towers at the Bowline Point Station is shown in Figure 4-14 of the DES.

Comment 19-3

It is noted that conditions relating to closed-cycle cooling at Bowline are being contested in an EPA adjudicatory hearing.

Response

A note to this effect has been added to paragraph 1.61.

Comment 19-4

Paragraph 1.61 improperly assumes that Section 326(b) of the Federal Water Pollution Control Act automatically requires closed-cycle cooling.

Response

Paragraph 1.61 has been revised to clarify the relationship between the requirement to backfit closed cycle cooling at certain older plants on the Hudson River and the provisions of Section 316(a) and (b) of the Federal Water Pollution Control Act Amendment of 1972.

Comment 19-5

Referring to Table 1-4, NRC licenses now call for cessation of once-through cooling operation by May 1, 1982 for Indian Point Unit 2 and September 15, 1982 for Indian Point Unit 3. Footnote 2 erroneously states the utility's present share of the Roseton Plant's capability.

Response

The information contained in Table 1-4 of the DES is taken principally from the New York Power Pool's annual report published in 1976 (New York Power Pool, 1976). Later editions of the report indicate that certain specific details no longer apply. Table 1-4 has been updated on the basis of information given in the Power Pool's report published in 1979 (New York Power Pool, 1979).

Comment 19-6

The discussion in Chapter 1 of the DES on other major projects on the lower Hudson River should examine more recent reports providing details of the overall planning in the area.

Response

Much of the information underlying the positions of the DES dealing with the characteristics of power plants on the Hudson River is taken from the New York Power Pool's annual report published in 1976 (new York Power Pool, 1976), the latest edition of the report available during the preparation of the DES. Changes in the long range plans of the member electric systems of the Power Pool have been made and reported in subsequent editions of the report. Where these changes bear on matters addressed specifically in comments on the DES or could materially affect the analysis contained on the DES, updated information is provided in FES. Among the sources of this information is the Power Pool's report published in 1979 (New York Power Pool, 1979), the latest edition presently available.

Comment 19-7

A number of corrections were provided by the Commenter concerning the capacity and other characteristics of present or planned power plants.

Response

The suggested amendments have been made wherever appropriate.

Comment 19-8

The Hudson River is a partially-mixed estuary, rather than the well-mixed estuary referred to in Paragraph 2.29 of the DES.

Response

Appropriate changes have been made in the text of the DES.

Comment 19-9

In paragraph 2.31, a definition of "normal" lower Hudson River freshwater flow should be provided.

Response

Appropriate amendments have been made in the text of the DES.

Comment 19-10

The utilities disagree with the statement in Paragraph 2.38 of the DES that the artificial thermal load imposed on the Hudson River raises the temperature of the receiving waters appreciably. The increase is not biologically significant relative to natural temperature fluctuations.

Response

Appropriate amendments have been made to the text of the DES.

Comment 19-11

The predominant animal list in the section in Chapter 2 on Upland Ecosystems in the DES should include the ruffed grouse, red fox, and gray fox. The quail should probably be eliminated from the group.

Response

The text beginning at paragraph 2.54 has been changed to reflect this comment.

Comment 19-12

Any species data collected by the N.Y.S. Department of Environmental Conservation in 1972 (see DES paragraph 2.57) should be presented here since the composition of the marsh might have changed between 1951 and 1972.

Response

Comment noted.

Comment 19-13

Figure 2-13 of the DES, Simplified Aquatic Food Web near Bowline Point, is somewhat misleading in that detritus also contributes to the base of the food web, along with primary producers.

Response

Modifications have been made to Figure 2-13 to show energy flow from detritus to the food web through bacteria.

Comment 19-14

Contrary to the statement made in DES paragraph 2.63, zooplankton concentrations were found to be highest in the Kingston area, not in the low to mid-salinity portions of the estuary.

Response

Paragraph 2. 65of the FES has been chanaged to include this information.

Comment 19-15

As stated in Paragraph 2.64 of the DES, copepods are certainly a dominant zooplankton species in the Hudson River estuary. However, unless copepod nauplii are included in this statement, other forms such as rotifers may predominate. (Orange and Rockland, 1977; Section 7.1.3.1.1).

Response

Under the assumption that to "predominate" is defined as dominance of numbers, then it is true that the recent study by Orange and Rockland (1977) shows that rotifers may at times predominate over copepods (exclusive of copepod nauplii). The text of Paragraph 2.64 in the FES has been changed accordingly.

Comment 19-16

Pertaining to Paragraph 2.66 of the DES, vertical migration patterns have been clearly demonstrated in macrozooplankton forms in the Hudson River, but this statement is questionable for most microzooplankton.

Response

The text of paragraph 2.66 of the FES has been revised to reflect this comment.

Comment 19-17

Pertaining to Paragraph 2.69 of the DES, evaluation of data subsequent to earlier reports has shown that the benthic community structure in the Bowline vicinity is not stable, but rather subject to yearly as well as seasonal variation. (Orange and Rockland, 1977; Section 8.1.3.3.1.1, p. 8.1.-102).

Oftentimes, the dominant organism is Amnicola rather than annelid worms. (Orange and Rockland, 1977a; Section 8.1.3.3.1.1, p. 8.1-118).

Response

The text of Paragraph 2.93 of the FES has been revised to reflect this comment.

Comment 19-18

The statement made in Paragraph 2.69 and 2.70 of the DES that the amphipod Gammarus is the dominant fish food in the Hudson River estuary is not necessarily true. Food preference or consumption depends on species, size, and season as demonstrated in Orange and Rockland, 1977; p. 10.1-125 for white perch, p. 10.1-157 for striped bass and p. 10.1-202 for Atlantic tomcod. Copepods and dipterans dominate the stomach contents during certain seasons.

Response

The text of Paragraph 2.72 of the FES has been revised to reflect this comment.

Comment 19-19

The bay anchovy spawns not only in mid-salinity regions of the Hudson, but also in saline waters along the Atlantic coast (Paragraph 2.74 of the DES).

Response

The text of paragraph 2. 74 of the FEIS has been revised to reflect this comment.

Comment 19-20

The evidence is that the larvae of fish are not simply carried downstream after hatching as suggested in paragraph 2.75 of the DES. The true phenomenon is much more complex than simple transport by currents.

Response

The text of Paragraph 2.75 of the FES has been revised to reflect this comment.

Comment 19-21

Striped bass have been omitted from the discussion of the lower Hudson River fishery in Paragraph 2.77 of the DES.

Response

Striped bass have been added to the discussion of the lower river fishery in Paragraph 2. 77 of the FES.

Comment 19-22

The statement: "Sport fishing is also an important use of the Hudson River's fishery resource," in Paragraph 2.79 of the DES is unsupportable; the implication that the Hudson River is the major contributor to sport fishing in the North Atlantic and New England Regions is incorrect. Estimates of contribution of Hudson River striped bass to Long Island Sound and the mid-Atlantic fishery are provided in McFadden (1977) at Section 7.10.7.

Response

Paragraph 2.79 has been modified in accordance with this comment. Although the Hudson River is not "the major contributor" to striped bass standing stock in the North Atlantic, the Hudson may provide spawning and nursery grounds for a substantial portion (up to 30 percent) of the fishery. Data cited in McFadden (1977) also shows that Hudson River stock composes the majority of sub-legal size striped bass collected in the vicinity of western Long Island. Further studies are required to define adequately the contribution of Hudson River striped bass stock to the Atlantic Coast population.

Nb

Comment 19-23

In reference to Paragraph 2.82 of the DES, the flowering dogwood is a protected species of plant in New York State. It is illegal to disturb this species in its natural environment. As a result of operation of a natural draft cooling tower, the dogwoods may be damaged by salt drift.

Response

This comment is addressed in a revised section on cooling tower drift and salt deposition beginning at Paragraph 4.85 of the FES.

Comment 19-24

Table 2-10 of the DES (Endangered, Extirpated, and Extinct Wildlife of New York State) should be confined to species which have been found or are likely to use the Hudson Valley. As it is, it gives the impression that many species could possibly be affected by development along the Hudson.

Response

Paragraph 2.80 of the FES, Endangered or Threatened Species, states that of the animals legally considered threatened or endangered in the State of New York, the Atlantic sturgeon and shortnose sturgeon are most likely to be affected by the power plant.

Comment 19-25

A more detailed discussion of the aquatic ecosystems in the Bowline and Roseton vicinities than presented in Paragraphs 2.86 to 2.109 of the DES may be found in Orange and Rockland (1977a) and Central Hudson (1977a) Section 6.1, 7.1, 8.1, 9.1, and 10.1.

Response

The description of aquatic ecosystems given in Chapter 2 has been modified and expanded as appropriate.

Comment 19-26

In addition to the effects of salinity changes mentioned in Paragraph 2.90 of the DES, seasonal succession of microzooplankton species is also linked to temperature and possibly to nutrients. Even if salinity were held constant, a seasonal pattern of species would occur.

Response

The text of Paragraph 2.90 of the FES has been revised to reflect this comment.

Comment 19-27

The definition of a "major consumer" of Hudson River water in Paragraph 3.21 of the DES should be clarified. Simply heating water does not consume it.

Response

As discussed in paragraph 4.23 of the DES, the rejection of waste heat from a power plant operating with open-cycle cooling promotes evaporation at a rate greater than would naturally prevail and effectively constitutes a consumptive use of water. In the case of the existing power plants on the Hudson River Estuary, this consumption is estimated to be of the order of 70 cubic feet per second, or 50 million gallons per day, on the basis of a rule of thumb provided by the U.S. Environmental Protection Agency (paragraph 4.24). An aggregate consumption of such magnitude is sufficient to support the statement that the power plants are major users of water.

Comment 19-28

Contrary to Paragraph 4.03 of the DES, it is unlikely that the Bowline Plant affects the flow regime of the estuary. All data indicate that its influence is not felt even over one-quarter of the river width.

Response

Paragraph 4.03 of the DES is an introductory statement listing the potential effects that the continued operation of the Bowline Point Generating Station might exert on the physical resources of the Hudson River Estuary. Each of these potential effects is treated as a cause of concern and is examined in subsequent portions of the DES. With respect to alteration in the flow regime of the estuary, the statement is made in Paragraph 4.26 of the DES that the effects associated with the rejection of waste heat from all of the existing power plants on the Hudson River are considered to be negligible.

Note

Comment 19-29

Not all proposed plants were included in the thermal model, nor should they be. (See comments on paragraph 4.14, below.)

Response

The comment includes the required response.

Comment 19-30

The near-field analyses have included recirculation considerations. (See McFadden, 1977, at Section 8.3.3 and Orange and Rockland, 1977a, at Section 3.1.3.3.3.)

Response

Thermal impact of the multiple-power-plant-operation on the Hudson River cannot be based on a near-field analysis which includes

Solely

only a simplistic formulation of the recirculation effect. Considering the ~~tidal-~~dominated flow conditions in the estuary, and the proximity of the locations of the major power plants, the thermal impact of the multiple-power-plants operation on the receiving waterbody of the estuary depends on (1) reentrainment, (2) recirculation, and (3) thermal interaction among the different power plants. Detailed discussions of these important effects are presented ~~in Appendix E~~ of the DEIS (Sec. 3.5.1) and also in Appendix E of the FEIS (Sect. 2.1). A relatively simple ~~but~~ correct formulation of the ~~reentrainment and~~ recirculation effects, under reversing flow conditions, is presented in Assessment of Technique, for hydrothermal prediction, by G. H. Jirka, G. Abraham and D. R. F. Harlemann (Sec. 8.3), Report No. 203, Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, MIT, July 1975.

Comment 19-31

The statement is made that natural conditions cannot be ascertained from field measurements. A good estimate of natural conditions can be made from measurements. The important question is how precise need the estimate be for impact assessment.

Response

The statement in Appendix E of the DEIS, "The situation in the Hudson River is such that the zones of thermal influence of the existing power plants overlap, making it impossible to ascertain through measurements alone the degree to which natural conditions are altered by each individual plant," is correct. The statement of the comment "a good estimate of natural conditions can be made from measurements" is wrong as long as power plants continue to operate during the measurements. The natural thermal conditions (ambient conditions), consistent with the statement of the state thermal standards as "before the addition of heat of artificial origin," can be determined based on field-measured water temperature data only if all the plants are shut down for a sufficiently long time period (more than a month). The statement of the comment "the important questions is how precise need the estimate be for impact assessment" is immaterial and indicates a lack of understanding of the hydrothermal phenomena which control the thermal impact of multiple-power-plant-operation on the Hudson River.

Comment 19-32

Statistical analysis of the thermal field study results used to obtain the 2 to 6 dilution indicate that the frequency of occurrence of excess surface temperatures of 7.5 is less than 1 percent and that 50 percent of the time, the maximum excess surface temperature of the time, the maximum excess surface temperature is about 4°F. Further, although dilution ratios of 6 to 9 were computed by the ORNL Model (Table 3.3.1, Appendix E), these values were not used here to assess the thermal effects.

Response

The results obtained in Sect. 3.3.1, Appendix E are strictly for the "Near-Field Analysis of Thermal Discharges" as indicated in the title of the section. The results based on the dilution ratios 2 - 6 cannot be utilized alone to determine the thermal impact of power plant operations on the Hudson River, since these models do not include any of the controlling hydrothermal phenomena in the estuary, consisting of (1) the reentrainment of the heated water at the discharge(s) of a power plant, (2) the recirculation of the heated water from the discharge(s) to the intake(s) of a power plant, (3) the reentrainment of the heated water from the discharge(s) of a power plant at the discharge(s) another power plant, and (4) the recirculation of the heated water from the discharge(s) of a power plant to the intake(s) of another power plant. The importance of all these effects which depend on the tidal flow conditions in the estuary, and the consequences of their exclusion in the near-field analysis of the discharges are clearly discussed on p. 3 - 18, Sec. 3.3.1, in Appendix E. It is further indicated that the realistic analysis of the thermal impact of power plant operations requires a far-field analysis which can include the critically important reentrainment and recirculation effects of the heated water from the multiple power plants on the Hudson River. Hence, the analysis of the thermal impact in the DEIS does not utilize directly the results of the near-field analysis based on the dilution ratios 2 - 6 which cannot incorporate the important effects of reentrainment and recirculation of the heated water.

Comment 19-33

Although a detailed evaluation of the thermal models used in the DEIS has not been conducted, the DEIS fails to address itself to the sensitivity of the models, the accuracy and limits of confidence associated with the results and the degree of prototype representativeness.

An overall review of the model and field study results presented in Appendix E indicates that the model (TMPTWO) overestimates the thermal impact in the vicinity of Bowline (2° to 3°F higher) and that in general, the agreement between the field observations and model results is very poor, considering that 1° to 2°F can make a large difference in whether there is a violation of criteria.

Response

1. The far-field mathematical model and its associated ESTONE computer code were applied to predict simultaneously (a) hydrodynamic, (b) thermal, and (c) salinity conditions in the Hudson River for two 6 - month periods 1 April - 30 September 1973 and 1974, without changing any coefficient and/or parameter in the model. Sensitivity studies are needed only if coefficients and/or parameters of a model need to be calibrated. The tidal-transient, one-dimensional discrete-element far-field model is a completely predictive model which does not require any major sensitivity study.

   "The accuracy and limits of confidence associated with the results and the degree of prototype representativeness" is self-evident based on the comparisons of its results with the field-measured data for the two 6 - month periods 1 April - 30 September 1973 and 1974.

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2. The general confrontation between the results of the mathematical models, including TMPTWO, and the field-measured data for the water temperature conditions in the Hudson River, including the vicinity of Bowline Point, is largely due to (1) the inaccuracies involved in the field measurements, and (2) the unrealiability of the data reduction methods used for obtaining the final temporal and spatial resolutions of the water information as presented in public documents. Detailed discussions of the field-measured data are included in Sect. 2.3 of the Appendix E of the FEIS.

Comment 19-34

The far-field model (ESTONE) used in the DEIS has not been adequately calibrated or verified.

Response

"The far-field model (ESTONE) used in the DEIS" does not require calibration. It definitely has been validated for the Hudson River, (see Sect. 2.3, Appendix E of FEIS).

? where.

Comment 19-35

No reference is made here to the source of meteorological data and the effects of various meteorological parameters on the model results, i.e., if in-land meteorological data were used, what would be the effects on river temperature? Some sensitivity analyses of the meteorological parameters ought to be presented.

Response

The detailed discussions of the input data to the ESTONE computer code for the meteorological conditions are presented in Sec. 2.4 in the FEIS.

Comment 19-36

In all prediction cases (3, 4, 5, 6, 7 and 8) considered here, "proposed maximum thermal load" was used. These represent unrealistic worst case conditions. The plants did not, and will not, operate at 100 percent capacity for 100 percent of the time. It would be far better and more realistic to use the operating rates as given, for example, on Orange and Rockland, 1977a, Section 2.1.3.6.

Case 3 is a very unlikely condition. Since the river takes several days to equilibrate, it is more appropriate to multiply maximum load by some plant factor.

Cases 3, 4, 5 and 8 should be excised from the DEIS as irrelevant to this study.

Response

Power-plant-operation conditions were modified in the supplementary study for Appendix E of the FEIS.

Comment 19-37

The accuracy of the predicted temperature, two decimal places, is questionable, particularly in view of the predicted level of noncompliance with the numerical criteria of 1°F (0.4 and 0.3°F for Bowline and Roseton/Danskammer, respectively).

If the ORNL intends to use such accuracy and predict such fine point violations, the model must be bounded by confidence limits based on sensitivity to input data and comparison to field data.

Response

The results of the predictions were presented accurate to two decimal places based on the printed computer output. The discussions of the thermal impact, according to the considerations of the State Thermal Standards were not based on two decimal place accuracy. In the discussions of the text, although the water temperature predictions were indicated with two decimal place accuracy, the violations of the State thermal standards were discussed only based on approximately half a degree accuracy.

Comment 19-38

It should be noted that exceeding the 83°F criterion over 50 percent of the cross-sectional area of the river (Cases 3 and 4) assumed plants operating at 100 percent capacity.

Response

Comment noted.

Comment 19-39

Experience to date indicates that the plume is a surface phenomena and thus it is unlikely that cross-section criteria will ever be exceeded.

Response

The statement indicates a lack of understanding of the important hydrothermal phenomena which control the far-field thermal impact of multiple-power-plant-operation on a tidal-dominated estuary (see Sect. 23., Appendix E of the FEIS).

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Comment 19-40

As indicated in a letter to the Corps of Engineers of October 13, 1977, the near-field and and zone matching portions of the ESTONE model and associated documentation have not been made available to the utilities' consultants. Accordingly, it was not possible to examine, in any detail, the inputs to, operation of, and predictions made by these models.

Response

"The near-field zone-matching portions of the ESTONE model and its associated documentation" does not exist. ESTONE computer code which is the associated computer code of the tidal-transient, one-dimensional, discrete-element far-field mathematical transport model was forwarded to the utilities. The remaining documents are being prepared as ORNL reports.

Documents never provid to allow usage.

Comment 19-41

It appears a dilution ratio of 2 was used in arriving at the occurrence of surface temperatures in excess of 91°F. Although such a low dilution was reported, its occurrence may be very rare. Also, it is not clear whether the model includes thermal stratification.

The EPA recommendations are irrelevant to these considerations and reference to them is misleading and should be deleted.

Detailed triaxial thermal measurements in the vicinity of Bowline do not support the statement that certain state criteria would be exceeded occasionally.

Field observations do not support the ORNL conclusion of the occurrence of surface temperatures and up-river effects have to produce surface temperatures in excess of 83.5 F at Bowline and simultaneously have the minimum recorded dilution of 2 in order to approach surface temperatures in excess of 91 F at Bowline. Existing ambient temperature measurements and the ORNL's own far-field calculations do not support the occurrence of such high temperatures (83.5 F) at Bowline, particularly considering that the dilution must simultaneously be low.

Response

1. The statement "It appears a dilution ratio of 2 was used in arriving at the occurrence of surface temperatures in excess of 91°F" is not correct. The tidal-transient, two-dimensional model does not use simplistic formulations based on any form of dilution ratio which automatically excludes the critically important reentrainment and recirculation effects in the estuary. The two-dimensional model uses complete flow fields based on the near-field and far field zone-matched hydrodynamic conditions, which include (a) the far-field freshwater flow and tidal flow conditions, and (b) the near-field intake and discharge flow conditions. Hence, the effects of reentrainment and recirculation are automatically included.

The model approximately includes thermal stratification.

2. The EPA recommendations were deleted.

3. "Detailed triaxial thermal measurements in the vicinity of Bowline" were not available for the analysis.

4. Appendix E of the DEIS did not state any "ORNL conclusion of the occurrence of surface temperatures and up-river effects at Bowline and simultaneously have the minimum recorded dilution of 2 in order to approach surface temperatures in excess of 91°F at Bowline." The comment indicates a lack of understanding of the reentrainment and recirculation phenomena that control the thermal impact in a tidal-dominated estuary.

Comment 19-42

The conclusion that the surface width and cross-sectional area 83°F criteria would be exceeded at Bowline appears to be based upon the results of the ORNL TMPTWO model. As indicated above, the model does not produce realistic results even if one assumes that the input parameters used are reasonable. Existing field data show that the affected surface width and cross-sectional area are bounded by a temperature rise of 4°F or by 83°F at Bowline. These temperatures are substantially below the N. Y. State thermal discharge criteria. Even if the full-load temperature conditions assumed in the model were to occur, the frequency and duration of violations would be insignificant.

Response

TMPTWO model does produce realistic results. The statement of the comment is not founded. "Existing field data show that the effected surface width and cross-sectional area are bounded by a temperature rise of 4°F and 83°F at Bowline" was not available for the analysis. This data, even if it does exist, cannot be compared with model predictions unless there exists the necessary compatibility between the data and the hour of measurements and the model predictions.

Comment 19-43

There are no data to support the third conclusion. In addition, the statement that excesses in temperature increase with decreasing freshwater flow is not true. In fact, just the opposite is true.

When freshwater flows are low, more cooler ocean waters will come into the estuary and may thereby decrease rather than increase temperatures. ORNL apparently hypothesized that temperatures will increase as a result of lower dilution due to decreased freshwater flow.

Response

The statement of the comment "In addition, the statement that excesses in temperature increase with decreasing freshwater flow is not true. In fact, just the opposite is true," indicates a lack of understanding of the hydrothermal phenomena that control the far-field thermal impact of multiple-power plant-operation on the Hudson River. The statement of the comment "when freshwater flows are low, more cooler ocean waters will come into the estuary and may thereby decrease rather than increase temperatures" can only be true for natural conditions without any power plant operating on the estuary. The comment indicates a general misunderstanding of the controlling hydrodynamic phenomena in the estuary. Freshwater flow is associated with the tidal-averaged convective transport which is the primary thermal transport phenomenon that controls the excess temperature conditions caused by the thermal discharges. "More cooler waters will come into the estuary" by the general mixing transport, which includes turbulent diffusion and dispersion, which is the secondary thermal transport phenomenon that affects the excess temperature conditions caused by the thermal discharges. Hence, the comment is false.

Furthermore, based on the definition of the ambient water temperature conditions, according to the State thermal standards, as "before the addition of heat of artificial origin," cooling of the water temperature conditions in the estuary by the cooler ocean water entering the estuary, from the ocean end, with multiple-power-plant-operation conditions, is identically the same cooling effect, without the operation of the power plants as represented by the "clean river" conditions. Hence, the relative excess temperature conditions caused by multiple-power-plant operation on the Hudson River cannot be reduced by the cooler water entering the estuary under lower freshwater flow conditions. Hence the comment is also meaningless from excess water temperature considerations.

Comment 19-44

General Comments on ORNL Thermal Model

The findings presented in the DEIS pages 4-6 through 4-9 indicating the 83°F regulatory criterion would be exceeded under certain conditions (maximum cross sectional area average temperatures of 83.80, 83.87 and 83.42°F are predicted at Indian Point) are questionable due to the following flaws in the ORNL thermal analyses:

The model verification is inadequate.

The comparisons of the model predictions with the field data presented on pages 3-115 through 3.-117 of Appendix E are generally inadequate with maximum differences ranging up to approximately 3.5°F. Differences for the 1974 verification period are given below:

Month	Days Showing Considerable Discrepancy	Discrepancy (Average Band-Field Data Range (F)
April	9-23	2.5 - 3.5
May	1-30	1.5 - 3.0
June	1-18, 27-30	2.0 - 3.5
July	1-5, 14-20	1.5 - 2.5
August	1-14	3.0 - 3.2
August	14-19	2.0 - 3.0
September	10-20	2.5 - 3.0

Discrepancies of these magnitudes between model predictions and field data are unacceptable for an analysis which purports to predict excesses of less than 1°F. Model predictions based on the ORNL verification are meaningless, particularly for critical periods when ambient temperatures are within 3 or 4 degrees of the regulatory criterion. For example, major discrepancies are noted for the critical period July 21 through August 14. The fact that the model overestimates the field data by more than 3°F indicate that the actual cross-sectional area average temperatures for the cases presented are probably nearer 80°F than 83°F.

An additional source of error in the verification may be in the conversion of the field data to cross-sectional averages. The field data were collected near the Indian Point intake and discharge and at other selected points. Comparison with model predicted "cross-sectional average temperatures" required that ORNL convert the field data. While considerable field data exist, it does not seem possible for ORNL to develop daily cross-sectional average field data for the entire period April through September 1974, without using some as yet unknown empirical conversion factor, which itself may be open to question.

The model scenarios for which the 83°F criterion is predicted to be exceeded are unrealistic.

Operation of all plants at maximum capacity over the same period of time, including the period needed for the river to equilibrate to such a steady-state condition, would be a rare occurrence when plant shutdowns, outages, maintenance and repair schedules and load cycling are considered. The model should be run with these factors incorporated for a realistic projection of the temperature regime in the river.

Inapplicability of EPA "Recommendation."

The DEIS and Appendix E refer to New York State water quality standards for thermal discharges as set forth in Part 704 of the New York Codes, Rules and Regulations. The New York thermal standards, as approved by EPA, however, do not include the EPA "recommendation" made in 1971 and 1973 (see references in DEIS, Appendix E, at p. 3-4) which had suggested that the mixing zone be limited arbitrarily to a 1,000 foot distance from the discharge.

Response

1. The statement of the comment "the model verification is inadequate" is not correct. The confrontation between the model predictions and the field-measured data is the result of the unreliability of the data (see Sect. 2.3 in Appendix E of the FEIS). The confrontation between two independent field-measured data sets is more pronounced than the confrontation between the model predictions and any single field-measured data set (see Sect. 2.3 in Appendix E of the FEIS).

2. The statement of the comment "An additional source of error in the verification may be in the conversion of field-data to cross-sectioned averages" is not correct. The field-measured data about the water temperature were not converted. Since the reduction of the field-measured data is always a part of the overall data acquisition program, no data reduction was attempted. The statement of the comment "while considerable data exists" is questionable, based on the considerations of the quality of the available data (see Sect. 2.3 in Appendix E of the FEIS). Furthermore, as stated above the responsibility of the reduction of the field-measured data, by "yet unknown empirical conversion factor" into a useful form always belongs to the group that had acquired the data.

3. Other power-plant-operation conditions for different fresh-water flow conditions in the Hudson River were considered in the Appendix E of the FEIS.

4. EPA "Recommendations" were deleted in the Appendix E of the FEIS.

Comment 19-45

Additional explanation is needed for the statement in Paragraph 4.25 concerning brackish or saline water "Evaporation."

Response

Paragraph 4.25 of the DES has been amended to clarify the statement regarding the evaporation of brackish or saline water.

Comment 19-46

The statement in Paragraph 4.27 that the operation of generating stations on the Hudson River estuary as a potential cause of degradation of the quality of the receiving waters has not been demonstrated by any evidence, and is in direct conflict with other statements in the DES.

Response

Paragraph 4.27 of the DES is an introductory statement acknowledging that heat and controlled amounts of contaminants are released in the liquid effluents from the Bowline Point Generating Station. As such, the effluents represent a potential cause of degradation in the quality of waters receiving the discharge from the power plant. Statements made in subsequent paragraphs indicate that monitoring has failed to reveal any measurable degradation in the waters of the Hudson River attributable directly or indirectly to the operation of the Bowline Point station.

Comment 19-47

Referencing the discussion of the liquid effluents from the closed-cycle cooling system discussed in Paragraph 4.41 of the DES, it is noted that chlorination for cooling towers may be continuous. It can be a problem under certain circumstances such as low chlorine demand or high hydrocarbon presence.

Response

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As mentioned in paragraph 6.20 of the DES, a closed cycle cooling system at the Bowline Point Generating Station would include dechlorination equipment to heat the blowdown, or liquid effluent, from the system. It may be anticipated that with such equipment in place and a chlorination schedule conforming to sound operating practices, the effluent from the system would meet applicable regulatory standards related to the discharge of chlorine.

Concern is being focused increasingly on the presence of hydrocarbons in the nation's surface waters and the possibility of producing toxic chlorinated compounds though the addition of chlorine in treating surface water for industrial and municipal uses. In accordance with the provisions of the Clean Water Act of 1977 (PL95-217), the U.S. Environmental Protection Agency is required to establish effluent standards reflecting the application of "best available technology" to control the release of a number of toxic substances including certain chlorinated hydrocarbons, from 21 categories of sources among which is the category of steam-electric power plants. Further, the U.S. Environmental Protection Agency has proposed regulations intended to control the release of toxic substances through the National Pollutant Discharge Elimination System program and to establish monitoring requirements related to these substances (43 FR 37078 et seq.)

The presence of certain toxic substances has been confirmed in waste streams of some coal fired power plants (U.S. Environmental Protection Agency, 1978). There is, however, little quantitative information on the source, transport and ultimate fate of these substances in the environment. Accordingly, it is impossible to estimate the potential risk associated with the release of chlorinated hydrocarbons, heavy metals or possibly other toxic substances from a closed cycle cooling systems at the Bowline Point Generating Station. It is expected that the effluents from such a system, if one is ultimately installed, would meet all applicable regulatory standards and conditons imposed through the National Pollutant Discharge Elimination System permit.

Comment 19-48

Referencing Paragraph 4.48 of the DES, it is noted that detailed field dissolved oxygen measurements in the thermal plume have been performed. No demonstrable reduction in dissolved oxygen was noted.

Response

There is no apparent disagreement between the statements made in this comment and that made in paragraph 4.48 of the DES. The latter, however, has been reworded in the interest of clarity.

Comment 19-49

Referencing paragraph 4.49 of the DES, it was noted that since August 1, 1976 the sulfur content in fuel oil burned at Danskammer has been 1.0% by weight. Since the switch from 2.0% sulfur oil at the plant, compliance with the federal 24-hour standard for sulfur dioxide has been achieved.

Response

A statement to this effect has been added to paragraphs 4.49, 4.51 and 4.70 of the DES.

Comment 19-50

The discussion in Paragraph 4.56 of the DES concerning a measurement program to observe the behavior of the plumes from the Bowline Point Station stacks is misleading.

Response

Paragraph 4.56 of the DES has been amended and now states that evidence indicates that the possibility of direct contact of the High Tor ridge by the plume is considered remote.

Comment 19-51

The ambient air quality standard for nitrogen dioxide is an average of the 24 hour concentrations over a consecutive twelve month period. The averaged monthly concentration (Table 4-6) should not be directly compared to this ambient standard as shown in the DES. In reality, the annual average value for the same period of time is 0.030 ppm, not 0.049 ppm.

Response

Comment noted.

Comment 19-52

Results of Orange and Rockland's analysis for environmental effects of cooling towers are presented in Orange and Rockland, 1977b; Section 5.2.

Response

Comment noted.

Comment 19-53

Referencing Paragraph 4.70, it is noted that since the switch from 2.0% sulfur oil at the Danskammer Plant, compliance with the federal 24-hour sulfur oxide standard has been achieved at Wheeler Hill Road Station.

Response

A statement to this effect has been added to paragraph 4.70 of the DES.

Comment 19-54

The analysis of potential salt drift from cooling towers at Roseton in paragraphs 4.71 and 4.72 of the DES assumed cooling tower specifications which are 20 percent higher than Roseton tower specifications, therefore resulting in smaller salt concentrations and fewer incidents of fog formation at ground level than would be expected with the towers determined to be appropriate by Central Hudson if cooling towers are required for Roseton.

Response

The analysis in the FES beginning at paragraph 4.102 includes the correct cooling tower parameters.

Comment 19-55

The analysis of potential salt drift from cooling towers at Roseton in paragraphs 4.71 and 4.72 of the DES assumed average year salinity levels in the Hudson River makeup water which are not indicative of salinity during drought years.

Response

Salinities during drought years has been considered in the revised analysis in the FES, beginning at paragraph 4.102 .

Comment 19-56

Contrary to the statement in Paragraph 4.75 of the DES, LMS has never developed models on adult striped bass entrainment.

Response

The text of Paragraph 4.79 of the FES has been revised to reflect this comment.

Comment 19-57

Contrary to the statement in Paragraph 4.76 of the DES, the Power Authority of the State of New York has never pursued a tag-recapture program for white perch or striped bass.

Response

The text of Paragraph 4.80 of the FES has been revised to reflect this comment.

Comment 19-58

The Corps comment on the "lack of adequate synthesis" of ecological data is not well founded. The January, 1977 (McFadden, 1977) report as well as the testimony and exhibits (Central Hudson 1977a, 1977b; Central Hudson, et al, 1977; Con Edison and Power Authority 1977a, 1977b; Ecological Analysts, 1977a, 1977b; McFadden, 1977; McFadden and Lawler, 1977; Orange and Rockland, 1977a 1977b; Stone and Webster, 1975, 1976; TI, 1977) submitted to EPA in July, 1977 contain such syntheses of the material the utilities believe to be of importance to the evaluation of effects on the fishery.

ORNL, a consultant to the Corps for this DES and its appendices, proposed the scope of work to be done (see Comments on Appendix B, below). ORNL was proposed as a consultant by the plaintiff Hudson River Fishermen's Association. ORNL also acts as consultant to EPA in the related EPA cases (see individual utility comments on the DES).

Response

These data have been incorporated into the FES.

Comment 19-59

The "First Annual Report for the Multiplant Impact Study of the Hudson River Estuary," was provided to the COE by letter dated September 4, 1975.

Response

These data have been incorporated into the FES.

Comment 19-60

It is inappropriate to divide yearly average deposition rates by 12 to determine potential for injury on a monthly basis. Substantial deposition can occur in a few hours if the meteorology is right. The degree of salt depositon will vary between months (for example, see Orange and Rockland, 1977b, Section 5).

The DES analysis calculated average annual salt deposition concentrations which mean very little when estimating damage done to foliage.

The use of short-term salinity concentrations prevalent during the summer months of drought years would yield higher deposition rates and would indicate the potential for damage to foliage during such periods. Such an analysis is included in Central Hudson 1977b. Similarly, with respect to Appendix E, Table 4.1.5 and Paragraph 4.3.4.2, the monthly River salinity values shown are typical of non-drought years and, during drought years, much higher salinity values could occur.

Response

The analysis of salt drift from cooling towers has been redone for the FEIS on a monthly average basis (see Appendix E of the FEIS and the FEIS beginning at paragraph 4.102).

Comment 19-61

Pertaining to DES paragraph 4.92, the amount of wetland to be eliminated at Greene County is detailed in both the Environmental Report (Power Authority, 1975a) and the application filed pursuant to Article VIII of the Public Service Law. (Power Authority, 1975b).

Response

Plans for the construction of the Greene County Power Plant have been cancelled by the Power Authority of the State of New York as of April 1979. Therefore, this reference to wetlands loss at the Greene County site has been deleted from the FES.

Comment 19-62

Pertaining to Paragraphs 4.94 through 4.119 in the DES, a more detailed and comprehensive discussion of expected impacts of Bowline may be found in Orange and Rockland (1977a), McFadden and Lawler (1977), Ecological Analysts (1977b).

Response

In the FES (Paragraphs 4.116), the discussion of Bowline Power Plant impacts has been revised to include new information from these references.

Comment 19-63

The differences in survival results for *Neomysis* at Bowline Point and Indian Point referenced in DES Paragraph 4.102 cannot be assumed to represent a disagreement without accounting for the possibility of differential net mortality and the comparability of temperature exposures during entrainment of this organism at the two plants. A more detailed discussion of *Neomysis* survival may be found in Orange and Rockland (1977a; Sections 8.2 and 8.3).

Response

The discussion of zooplankton impacts has been revised in the FES and reference to differential *Neomysis* mortality between Bowline Point and Indian Point has been deleted.

Comment 19-63a

Pertaining to comments made in DES Paragraphs 4.106 and 4.107, evaluation of ichthyoplankton entrainment abundance at the Bowline Point Generating Station may be found in Orange and Rockland (1977a; Section 9.2).

Response

The FES discussion of Bowline Point entrainment of fish eggs, larvae, and juveniles has been revised to include the information found in Orange and Rockland (1977a).

Comment 19-64

Pertaining to the statement made in DES Paragraph 4.108, only striped bass and white perch were analyzed in 1973 at Bowline Point; thus the unidentified larvae could have been *Alosa* spp., Atlantic tomcod or bay anchovy.

Response

The discussion of Bowline Point entrainment has been revised for the FEIS and the statement made in the DES paragraph 4.108 has been deleted.

Comment 19-65

With reference to DES Paragraph 4.111, the last sentence of this section invalidates the previous sentence, i.e. there was no problem. Also, a more detailed and comprehensive evaluation of entrainment survival information may be found in Orange and Rockland (1977a).

Response

This problem has been resolved by revising the discussion of entrainment at Bowline Point. The revised discussion presented in FES paragraph 4.128 includes new information from Orange and Rockland (1977a).

Comment 19-66

Pertaining to DES paragraphs 4.112 and 4.113, the definition of "normal" temperature exposure and ichthyoplankton survival is addressed in Orange and Rockland (1977a, Section 9.4). Atlantic tomcod survival for 1976 and 1977 may be found in Orange and Rockland, 1977a, Section 9.4.

Response

These sections have been rewritten for the FES (paragraph 4.129) and the statements in question have been deleted.

Comment 19-67

There is no inherent reason why the 27% ORNL mortality estimate for striped bass at Roseton supports the 24% ORNL estimate at Bowline. No rationale is presented for making the assumption in the last sentence of this section. Although limited data were involved, in contrast to the 1975 Roseton data referred to here, survival of yolk-sac striped bass at Lovett in 1976 was estimated at 100%. (EA, 1977a; Section 1.3.2).

Response

This section has been rewritten for the FES (paragraphs 4.128) and the statement in question has been deleted.

Comment 19-68

Reference to the sampling method used to estimate striped bass entrainment mortality at Indian Point is inadequate (DES Paragraph 4.115). Enough is known about net mortality problems in the survival studies at Indian Point to elaborate here. The probable bias introduced by the sampling method at Indian Point should be discussed. (See EA, 1977a; Sections 1.3 and 1.3.2).

Response

This section has been rewritten for the FES (paragraphs 4.128) and the statement in question has been deleted.

Comment 19-69

The last sentence of DES paragraph 4.116 should read, "Young fish in their first year of life generally dominated impingement collections".

Response

This section has been rewritten for the FES (paragraphs 4.134) and the statement in question has been deleted.

Comment 19-70

As presented in DES paragraph 4.118, unadjusted impingement rates, without scale-up, provide lower estimates of impingement at Bowline Point (Orange and Rockland, 1977a, Section 10.2). Employment of a collection efficiency of 0.5 by ORNL is not supported by existing data. (Orange and Rockland, 1977a, Section 10.2.3.1.3, p. 10.2-10).

Response

This section has been rewritten for the FES (paragraphs 4.131), and the statement in question has been deleted.

Comment 19-71

Impingement survival at Bowline Point as mentioned in DES paragraph 4.119, may be found in Orange and Rockland, 1977a, Section 10.3.

Response

The sections have been rewritten in the FES (paragraphs 4.131), and the statement in question has been deleted.

Comment 19-71a

Pertaining to paragraph 4.126 of the DES, chlorination has been discontinued at the Roseton and Danskammer plants in favor of mechanical condenser cleaning.

Response

The section has been rewritten in the FES (paragraph 4. 143) and the statement in question has been deleted.

Comment 19-72

Contrary to the statement made in DES paragraph 4.134, data regarding numbers of ichthyoplankton of key fish species entrained at the Roseton station through the year 1976 are given in the evidentiary material filed with EPA Region II on July 11, 1977 (Central Hudson, 1977a).

Response

This section has been rewritten for the FES (paragraphs 4.149) to include the recently available data on 1976 entrainment at Roseton.

Comment 19-73

The findings of Ecological Analysts (1977a, 1977b) should be added to the discussion of cumulation impacts on phytoplankton, zooplankton, and benthos found in DES paragraphs 4.140 to 4.152.

Response

The results of this recent study have been included in the FES when appropriate. See paragraphs 4. 162 to 4.172.

Comment 19-74

Contrary to the statement made in DES paragraph 4.158, insufficient data exist to allow the statement that Atlantic tomcod yolk-sac larvae are distributed throughout the water column. (McFadden, 1977 at Section 14.42, p. 14.14).

Response

The discussion of multiplant entrainment effects has been rewritten for the FES (paragraphs 4.173), and the statement in question has been deleted.

Comment 19-75

The estimate of entraiment for Unit 1 of Indian Point in Table 4-19 of the DES is based on Unit 2 concentrations rather than on river concentrations as stated in the footnote. In addition, "August 1974" in footnote d of Table 4-19 should be changed to September 1974.

Response

This table has been deleted from the FES.

Comment 19-76

Contrary to statements made in DES paragraph 4.162, fish impingement data (all species) are reported monthly as well as annually in utility reports. (See generally the "Indian Point Impingement Study" reports for 1972-73, 1974 and 1975 which were provided to the Corps of Engineers by letters dated February 20, 1975, December 11, 1975 and December 20, 1976, respectively). Furthermore, reports prepared for Orange and Rockland (LMS, 1974; LMS, 1975; LMS, 1976 and Orange and Rockland, 1977a; Section 10.2) report on impingement data of striped bass, white perch, Atlantic tomcod, and other species.

Response

This section of the report has been rewritten in the FES (paragraphs4.180). Where appropriate the revised version provides more detailed information on Hudson River power plant impingement of fish.

Comment 19-77

Power plant impacts on blueback herring and shortnose sturgeon were not calculated but were discussed in McFadden (1977 at p. 14.19). Accordingly, despite the implication in the DES at paragraph 4.162, the equilibrium reduction equation was not applied for impact assessment on these two species.

Response

This section has been deleted from the FES.

Comment 19-78

The impingement data presented in Table 4-22 of the DES should not be expressed as number per million gallons, but rather as number per million cubic meters. In addition, although not significantly different, the data presented in this table should be updated in light of the data presented in Supplement 1 to the January, 1977 report (McFadden and Lawler, 1977). The derivation of the impingement rates at Cornwall is unclear, since the plant does not exist. Further, it is improper to consider the Cornwall project here as it has no bearing on the subject proceedings, nor can it be used as a determinant for the installation of cooling towers in 1982 when it will not become operational until 1988-89.

Response

Table 4-22 (DEIS) has been deleted from the FES.

Comment 19-79

It is unclear why, in Table 4-23 of the DES, different factors were applied to the impingement estimates at Bowline, Indian Point, and Roseton when the cooling system is changed from once-through (OT) to closed-cycle (CC). For instance, the impingement estimate at Bowline with CC cooling is 2% of that with OT cooling, whereas at Indian Point it is about 9% and about 4% at Roseton. The higher factors applied to the Roseton and Indian Point impingement estimates require justification.

Response

Table 4-23 (DES) has been deleted from the FES.

Comment 19-80

Instead of the use of closed-cycle cooling, modification of all intakes with the installation of screens or deflection devices could also reduce impingement, and would cost less than cooling towers. (See, for example, Stone and Webster, 1975, 1976a and 1976b; and Exhibits 16 and 22 of the July 11 filing with EPA, all of which have been supplied to the Corps of Engineers).

Response

Studies on the use of nets in front of the intake structures at Bowline Point are summarized in the Bowline Point impingement section of the FES (paragraph 4.138). In addition, the concept of using screens or deflecting devices to reduce impingement impacts is disccussed in Paragraphs 6.58 through 6.60, Modification of the Present Permit--Improvements to Plant Intake.

Comment 19-81

Unlike Indian Point Unit 2 where impingement collection efficiency may be less than 100% due to the air bubbler and once-a-day washing of the vertical fixed screens, the collection efficiency at Bowline and Roseton should be very high. (See Orange and Rockland, 1977a, Section 10.2). Application of a collection efficiency of 0.5 to Bowline and Roseton impingement estimates, as discussed in DES paragraph 4.170, surely results in a gross overestimation of impingement impacts at these plants.

Response

This section has been deleted from the FES.

Comment 19-82

In paragraph 4.172 of the DES it is stated that the extent to which the Ricker theory is applicable to estimating the ultimate effects of power plant generation on Hudson River fish populations is presently unresolved. Supplement 1 (McFadden and Lawler, 1977) to the January 1977 Report (McFadden, 1977) presents a detailed analysis and application of Ricker's stock-recruitment theory in estimating the ultimate effects of power plant operation on Hudson River fish populations.

Response

Information in Supplement 1 (McFadden and Lawler, 1977) have been used in preparation of the FES. A discussion of the applicability of the Ricker theory is included in material beginning at paragraph 4.187 .

Comment 19-83

Values of percentage losses from entrainment and impingement given in Table 4-24 of the DES have been updated in McFadden and Lawler (1977) at p. 2-VIII - 36, 37.

Response

These data have been used in the FES.

Comment 19-84

The issue discussed in paragraphs 4.180 and 4.181 of the DES is not the existence of striped bass compensation but its extent and operation. The existence of compensation has been shown empirically for striped bass populations. The commercial fishery catch data provide precisely the long time-series which the DES requires to "determine empirically the existence of compensatory relationships within a fish population."

Response

The most recent Utility analyses to demonstrate empirically the existence of compensation in striped bass and white perch populations of the Hudson River are evaluated beginning at paragraph 4.192 of the FES.

Comment 19-85

Estimates of entrainment mortality (f_c) presented in Table 4-25 of the DES are obsolete in light of the updated 1975 and 1976 entrainment survival data available since the DES was issued.

Response

A discussion of entrainment mortality utilizing more recent data can be found beginning at paragraph 4.173 of the FES.

Comment 19-86

The large ranges of f_I factors presented in Table 4-27 of the DES are due not to the quality of the data, but to the wide variations in the distribution of striped bass ichthyoplankton from year to year and from one plant site to another. More recent data can be found in McFadden and Lawler (1977).

Response

More recent data have been incorporated into the FES at paragraph 4.173 .

Comment 19-87

Instead of the values for entrainment mortality given in Table 4-26 of the DES, the Corps should use the results from larval table sampling. The larval table results are much better mortality estimates.

Response

These recent data have been used in the FES.

Comment 19-88

The interpretation of the analyses pertaining to the best lag time to use in pairing spawners with the resulting recruits may be more complex than the presentation given in paragraph 4.187 of the DES.

Response

More recent analyses of the appropriateness of the Utilities choice of a 5-year lag time in matching data on spawners and recruits for striped bass in the Hudson River is presented beginning at paragraph 4.229 of the FES.

Comment 19-89

McFadden and Lawler (1977) presents a revision of the analysis of population density effects on growth of young striped bass as given in paragraph 4.188 of the DES. After corrections in the raw data, the negative relationship between density and growth reported in the DES is no longer apparent. However, this does not mean that such a relationship does not exist. The Corps should refer to studies of the Roanoke Albemarle system by the University of North Carolina at Raleigh (Hassler and Hogarth, 1970) and on the West Coast (Chadwick, 1964; 1968). (See white perch work by Mansueti, 1961 and by Hergenrader and Bliss, 1971, on growth and population density).

Response

The most recent Utility analyses to demonstrate empirically the existence of compensation in striped bass and white perch populations in the Hudson River are evaluated beginning at paragrah 4.187 of the FES.

Comment 19-90

Section 2-IV of McFadden and Lawler (1977) provides an extensive analysis indicating "the range of mortality rates resulting from power plant operations that could be offset by compensatory responses and the degree of offset".

Response

Data from McFadden and Lawler (1977) have been incorporated into the FES at paragraph 4.187 of the FES.

Comment 19-91

Utilities disagree with all four contentions of the staff of the Oak Ridge National Laboratory presented in paragraph 4.192 of the DES regarding the form of compensation function used in the Lawler, Matusky, and Skelly model of long-term fish population reduction.

Response

The model referred to is no longer used by the Utilities to estimate long-term impacts and has been deleted from the FES.

Comment 19-92

In reference to the values given in paragraph 4.194 of the DEIS for entrainment mortality used in the Oak Ridge National Laboratory model runs used to estimate long term impacts to striped bass, mortality for organisms entrained in a closed cycle cooling system is 100 percent.

Response

This model is no longer used by the Oak Ridge National Laboratory and has been dropped from the FES.

Comment 19-93

The large reduction in striped bass adult population size predicted by the Oak Ridge National Laboratory model as presented in Table 4-31 and discussed in paragraphs 4.196 and 4.197 of the DES is due principally to the modification of the compensation function as proposed by Lawler, Matusky, and Skelly. Utilities disagree with the modification of the function. Also, Utilities disagree with the inclusion of the effects of the Danskammer and Lovett plants since their impacts on fish populations is already reflected in the baseline conditions.

Response

This model is no longer used by Oak Ridge National Laboratories or the Utilities to predict long-term impacts and has been dropped from the FES.

Comment 19-94

The Utilities agree that the runs of the Oak Ridge National Laboratory population model that use no compensation, as discussed in paragraph 4.198 of the DES, are unrealistic.

Response

This model is no longer used by the Oak Ridge National Laboratory and has been dropped from the FES.

Comment 19-95

The "increase" in the magnitude of effect from annual loss of young-of-the-year compared to the reduction in adult stock after 40 years as predicted by the Oak Ridge National Laboratory population model and discussed in paragraph 4.199 of the DES is due to the form of the compensation function used. Utilities disagree with the form of the Laboratory's compensation function.

Response

This model is no longer used by the Oak Ridge National Laboratory or the Utilities and has been dropped from the FES.

Comment 19-96

Utilities disagree with Oak Ridge National Laboratory in restricting compensation to the entrainable life stages only in their population model of long term impact, which is discussed in paragraph 4.202 of the DES. The Laboratory has offered no evidence that compensation does not occur during the impingeable life stages.

Response

This model is no longer used by Oak Ridge National Laboratory to predict long-term impacts and has been dropped from the FES.

Comment 19-97

The equilibrium model (i.e. Equilibrium Reduction Equation [ERE]) discussed in paragraph 4.203 of the DES is not an extension of the Lawler, Matusky, and Skelly model used by Oak Ridge. The ERE was developed independently by Texas Instruments.

Response

This statment has been removed from the FES.

Comment 19-98

The long-term reduction in the adult population level of striped bass in the Hudson River as predicted using the Real-Time Life-Cycle Model has been revised upward to 8 percent (McFadden and Lawler, 1977) from the value of about 5 percent given in the DES in paragraph 4.204. Also the characterization of the Oak Ridge National Laboratory population model in the DES as employing "strong compensation" is completly unfounded. As indicated above, the largest amount of compensation in Table 4-31 (KXO/KX = 0.5) corresponds to an extremely low level of alpha (1.4). The percentage reductions in Table 4-32 at KXO/KX = 0.5 (13 to 15%) correspond to a more realistic, yet still conservative, level of alpha (3.2).

Response

An analysis of the Real-Time Life-Cycle Model is given in the FES beginning at paragraph 4.241 . The Oak Ridge National Laboratory no longer uses the population model to predict long-term impacts, and it has been dropped from the FES.

Comment 19-99

Much more important reasons for the differences in the impact predictions obtained by the Utilities and the Oak Ridge National Laboratory, than those given in the DES beginning at paragraph 4.205 are:

(1) The amount of compensation operative;

(2) Differences in entrainment survival estimates; and the 50% impingement collection efficiency erroneously applied to Bowline and Roseton data by ORNL.

Response

Oak Ridge National Laboratory no longer uses the population model discussed in the DES and has made no new predictions of long-term impacts to fish populations. Comparisons with present Utility estimates are not possible in the FES.

Comment 19-100

Ricker's methodologies for assessment of exploitation may be applied in a manner which allows natural mortality to be held to be negligible or in a manner in which exploitation occurs over a period of months during which a high rate of natural mortality occurs. Texas Instruments (TI) in applying Ricker's methodologies initially elected to apply them in a manner which discounted concurrent natural mortality. Subsequent to the issuance of McFadden (1977) in which this methodology was developed and presented (Section II), it was pointed out to TI that a more appropriate approach would be to account for natural mortality throughout the rather long period of exposure to power plants. This is the reason for the use of the term "misinterpretation". Utilities believe the use of the word "error" in paragraph 4.206 of the DES is incorrect.

Using the revised interpretation of Ricker's analysis and the recalibration of the LMS Model results in a prediction of multi-plant impact at 40 years of 8% (McFadden and Lawler, 1977, Section 3-VIII).

Response

The reference to an error in analyses has been removed from the FEIS. An analysis of more recent Utility estimates of long term reduction in fish populations begins at paragraph 4.205 of the FES.

Comment 19-101

It is stated in paragraph 4.207 in the DES that the population models used to predict impact to fish populations by the Utilities and Oak Ridge National Laboratory were different in that the Utility analysis used a level of compensation stronger than the strongest case considered by Oak Ridge.

The most important difference in the application of the models however, was Oak Ridge's disabling of the left limb of the compensation function.

Response

These models are no longer used to predict long-term impacts and have been removed from the FES.

Comment 19-102

It is stated in paragraph 4.208 of the DES that Oak Ridge National Laboratory noted a larger effect of impingement in their runs of the population model than did the Utilities in their runs of the same model. The important effect of impingement when strong compensation was assumed in the Oak Ridge runs was thought to account for the difference. As explained in Comment 19-98, "strong compensation" was not assumed in any of the Oak Ridge runs. Inflated impingement rates due to the unfounded application of a 50% collection efficiency at Bowline and Roseton probably caused the greater estimate of impingement impact.

Response

These models are no longer used to predict long-term impacts and have been removed from the FES.

Comment 19-103

It is stated in paragraph 4.210 of the DES that differences in values of entrainment mortality were probably not responsible for the larger differences in estimates of long-term impacts to the adult striped bass made by the Utilities and the Oak Ridge National Laboratory. The Utilities believe that differences in the values chosen for entrainment mortality do contribute to the differences in impact predictions. Oak Ridge used three different levels of intake factors. These are not all similar to the values used by the Utilities.

Response

These older models are no longer used to predict long-term impacts and have been dropped from the FES.

Comment 19-104

In paragraph 4.219, the notion of arriving at an equitable distribution of benefits and costs is mentioned. However, the Corps of Engineers has not provided any cost/benefit evaluation for the alternatives proposed. Furtheremore, no cost/benefit or comparative evaluation of alternatives to closed-cycle cooling has been provided in the DES.

Response

As indicated in paragraph 4.02 of the DES and the introductory portions of section 6 dealing with alternatives, the analysis presented in the DEIS focuses on the costs and benefits associated with alternaitve options available to the District. However, the analysis encompasses cooling alternatives (paragraphs 6.09 through 6.56 of the DES) and alternatives to closed cycle cooling (paragraphs 6.58 through 6.62 of the DEIS), although regulatory decisions on these matters are not within the purview of the District. This is consistent with the directives of the National Environmental Policy Act on the question of alternatives and allows the District to assess the implications of its own action under a range of conditions representing the possible outcome of actions taken by other agencies.

Comment 19-105

The visual impact of the Bowline Point Generating Plant will be exacerbated by the construction of the proposed cooling towers.

Response

A discussion of the visual impacts of the Bowline Point Station are given beginning at Paragraph 4.251 of the FES.

Comment 19-106

Referencing paragraph 4.224 of the DES, Orange and Rockland has optimized the cooling tower design to the lowest possible height, which is 393 feet. The base diameter would be 315 feet.

Response

A note has been added to Figure 4-14 of the DES to indicate that the artist's impression given in this figure is based on a preliminary design and that the height and base diameter of the towers have been reduced according to a later design. The appropriate changes have been made in paragraph 4.224 and 6.18 of the DES.

Comment 19-107

Utilities support the fact in paragraph 5.10 of the DEIS that there are alternatives to cooling towers, which could be implemented at far less cost, in lieu of cooling towers, if impacts were deemed unacceptable. These alternatives could include modified operation of the circulating water system to optimize entrainment survival, modification of the intake structure to reduce impingement, or stocking Hudson River striped bass. (See Orange and Rockland, 1977a; Section 9.4.4.3.3, p. 9.4-58; Stone and Webster, 1975, 1976a, 1976b and Texas Instruments, 1977.)

Utilities disagree that it is impossible to predict how successful alternative measures would be, based upon the research results reported above.

Response

Comment noted

Comment 19-108

Paragraph 5.14 of the DES notes that the presence of polychlorinated biphenyl compounds in the Hudson River is a factor that warrants consideration as elements of risk associated with the long-term operation of the power plants with closed-cycle cooling. The comment notes that the presence of these compounds has resulted in the prohibition of commercial fishing in the Hudson River and in the limitation of the number of fish taken by sports fishermen for consumption.

Response

Mention is made in paragraph 2.37 of the DES of the ban on commercial fishing in the Hudson River and the advisory on limiting the intake of fish from the Hudson River as a result of elevated levels of polychlorinated biphenyl compounds (PCB's) in the river. Available information, given in Figures 2-16 and 2-17 of the DES, indicates that annual commercial landings in the Hudson River Valley have been of the order of 300,000 pounds for American shad and less than 100,000 pounds per year for alewives and striped bass.

This ban represents a monetary loss to the commercial fishermen of the Hudson River Valley but, clearly is unrelated to the operation of the Bowline Point Generating Station and the other power plants on the river. In the long term, it appears reasonable to suppose that the present prohibition on the discharge of PCB's, possibly accompanied by efforts to decontaminate the river, will lead to reduced levels of these compounds in the river. Commercial fishing may resume and the potential effects of the power plants on the fishing industry then become a relevant consideration. It is difficult, however, to estimate the magnitude of these effects in terms of financial losses for a number of reasons. Principal among them is the uncertainty concerning the effects of the power plants on populations of fish in the Hudson River, as discussed in detail in various sections of the DES.

Beyond this uncertainty, several factors must be considered in relating possible reductions in standing stocks to financial losses to the regional fishing industry. Market conditions, such as the demand for a particular type of species of fish and the value of the product, rather than standing stops could be the principal determinants of the commercial catch. The seasonality of commercial landings may be another important factor in terms of the size and nature of the fishing industry that can be maintained. Nonetheless, a reduction in standings stocks can, in general, be related to a reduction in catch-per-effort and, in turn, to a loss in the earnings of commercial fishermen.

Comment 19-109

Orange and Rockland Utilities, Inc. and Central Hudson Gas and Electric do not agree that the Corps has any legal authority to place operating restrictions on the Bowling Point or Roseton generating stations.

Response

Current regulations authorize the District Engineer to re-evaluate the circumstances and conditions of a permit either on his own motion or as the result of periodic progress inspection, and to initiate action to modify, suspend or revoke a permit as may be made necessary by considerations of the general public interest. All factors which may be relevant must be considered in this review, including conditions of conservation, economics, aesthetics, general environment concerns, historic values, fish and wildlife values, safety, land use, water quality, and in general, the needs and welfare of the people.

Comment 19-110

It is believed that problems associated with backfitting a plant designed for once-through cooling, the aesthetic impact of massive towers and their plumes, and 100 percent mortality of entrained organisms will probably be ecologically disadvantageous along with salt drift.

Response

Comment noted.

Comment 19-111

Paragraph 6.48 of the DES discusses measures aimed at reducing the amount of cooling water that is withdrawn from the Bowline Pond and circulated through the power plant. Based upon organism thermal tolerance information, the utility believes that careful consideration must be given to the operating mode of the recirculating water system.

Response

Comment noted.

Comment 19-112

Paragraph 6.57 of the DES notes a number of other mechanisms in addition to thermal shock through which biota are injured or destroyed. However, larval table data at Bowline show that temperature is the main determinant of mortality.

Response

Comment noted.

Comment 19-113

The discussion of potential improvements to plant intake structures in paragraph 6.58 - 6.60 of the DES should be expanded.

Response

An expanded discussion of the possibility of installing alternative intake structures at the Bowline Point Generating Station now replaces the discussion given in paragraphs 6.58 through 6.60 of the DES.

Comment 19-114

Paragraphs 6.61 and 6.62 of the DES discuss the concept of a comprehensive management program within the New York Power Pool which would, inter alia, restrict certain power plant operations depending upon ecological conditions. This concept should be explored in greater detail and should particularly address the responsibility of the member utilities to supply adequate and reliable electric service at lowest possible cost to the consumers in New York State. The Corp's limited authority over implementing such a program should be addressed.

Response

No statement made in the DES is intended to be contradictory to the substance of this comment. As mentioned in paragraph 6.62 of the DES, the notion of "ecological dispatch" is a suggestion based on limited ecological information, with evident need for more data and analysis to formulate a comprehensive management program. Editorial and other changes have been made in Paragraph 6. 70 of the FES to emphasize that "ecological disptach" can be considered at present only as a possibility of undertermined ecological, technical and economic viability.

Comment 19-115

In the first sentence in paragraph 6.77 of the DES, change Bowline Point to Roseton. The last sentence should read: "The increased fuel consumption is estimated to be on the order of 2.5 million barrels of fuel oil per year with a spot market value in excess of $45 million per year."

Response

The obvious error in paragraph 6.77 of the DES has been corrected. A revised estimate shows that the additional fuel consumption associated with the suspension of the Roseton is 2.5 million barrels of fuel oil per year as indicated in this comment, and not 2.0 million barrels per year as indicated in the DES. In order to maintain consistency throughout the analysis, a value of $37.5 to $40 is assigned to this increase in consumption on the basis of 1976 spot prices of fuel.

Comment 19-116

It is misleading in paragraph 7.04 to lump all short-term uses of man'e environment along the estuary as if they all caused reductions in productivity.

Response

Editorial and clarifying changes have been made in paragraph 7.04 of the FES.

Comment 19-117

The implication in paragraph 8.09 of the DES that striped bass are selectively stressed is incorrect.

Response

The argument presented in paragraph 8.09 of the DES is an expansion of the possibilities identified in paragraph 8.07 as potential irreversible, or permanent impacts. With the present state of knowledge of the aquatic ecosystem of the Hudson River estuary, the argument is, of necessity, based mostly on theoretical considerations. Among these is the possibility that striped bass are selectively stressed with respect to other species because of different characteristics in life cycles of the fishes. For example, the particular spawning habits of striped bass could, in principle, render their progeny more or less susceptible to entrainment and impingement. The sensitivity of eggs and larvae to entrainment and survival among impinged juveniles in many cases is known to vary from species to species. It is conceivable, therefore, that one or more species could be selectively stressed and that the irreversible impacts identified in paragraph 8.07 of the DES could materialize.

Comment 19-118

Appendix B is incomplete in that it does not contain a copy of the September 22, 1976 Order of Judge Metzger in Hudson River Fishermen's Association, et al., v. Orange and Rockland Utiltiies, Inc., et al., (72 Cir. 5460).

Response

A copy of the Order has been included in Appendix B in the FEIS.

Comment 19-119

Appendix C suggests that the generation from Roseton and Bowline is not necessary, speculating that other generation sources are or will be available. These unwarranted conclusions are completely incorrect.

Response

Appendix C provides detailed information to support certain findings and conclusions made in the body of the report. A statement to this effect has been added to the introductory paragraph of the Appendix to ensure that it's intended purpose is clearly defined.

Responses to the more specific comments that follow will effectively address the broad points of contention contained in the above comment.

Comment 19-120

In devising the long-range plans of the New York Power Pool, the investor-owned member utilities are limited by a number of external constraints. These companies have severe financial constraints on the investment of new capital and are required by their managements and stockholders, and by regulatory authorities, to justify the commitment of funds to new facilities. While the projection of future load is an important factor in the decision to construct a plant, this factor does not stand alone. The environmental constraints on new facilities, the attitude of, and legal restraints imposed by, local governments, the local tax burden on a facility, the attitude and productivity of the labor environment, and the price resistance of customers all confine the planning for the construction of new facilities.

Response

A discussion on the significance of projections of peak load in planning additions to generating capability is given in the third paragraph on page C-11 of the DES. In the discussion it is pointed out that all projections represent the primary basis, and not the exclusive basis, for planning. The factors enumerated in the above comment compliment the information given in the DES and point to the advisability of allowing for contingencies in long-range generation plans. A discussion of the effects of such contingencies is given on pages C-18 through C-20 of the FES.

Comment 19-121

National policy requires the limitation, to the extent possible, of the need to burn oil. Accordingly, the long-range plans of the Power Pool now envision expansion of power generation using coal and uranium fuel.

Response

A description of the Power Pool's long range plans given in the first full paragraph on page C-18 of the DES indicates that nuclear fueled power plants constitute approximately 64 percent of the additional generating capacity scheduled to be installed between 1976 and 1991, with coal and oil fueled power plants constituting respectively 15 percent and 9 percent of additional capacity.

Comment 19-122

Changing environmental and regulatory requirements and procedures have limited the Pool's ability to estimate the total time needed for planning and construction of new generating units. Two major uncertainties -- a return to the higher trends of long-term load growth rates as the effects of the national recession ease, and a delay in bringing units on the line must be considered in planning. In developing the Pool plan, the most reasonable estimates permit allowance for the detrimental effects of either, but not both, of these two major uncertainties. The Pool's present forecasts reflect the lower growth rate of the past three years and the impact of conservation efforts. These lower growth rates run counter to both historical trends and to the fact that the trend of consumption of other forms of energy for other purposes has not experienced similar declines.

The current experience is that the overall time required to put generation into operation is actually increasing due to several factors, including regulatory delays, construction delays, enforced regulatory modifications, and litigation. Utilities believe that it is becoming increasingly more difficult for new generation to become productive in the anticipated time.

The Power Pool plan recognizes the two major uncertainties, provides for the occurrence of one or the other (but not both), and develops a plan which projects reserves of large magnitude, if all occurs according to assumptions; and it includes an optimistic perspective of the time required to implement the plan. However, the plan is not the fact; and if a fortuitous set of circumstances should combine to permit perfect implementation, action obviously would be taken in later plans to delay future, uncommitted plants. Each plant must receive a certificate for construction, on an individual basis, in a procedure in which the then current need for the plant is thoroughly examined.

Response

The summary of the New York Power Pool's long range generation plan given on pages C-18 through C-20 of the FES confirms the prediction that adequate reserve margins could not be maintained with both a load growth higher than anticipated and additions to capacity coming on line on a delayed schedule. As indicated in the above comment, the addition of new capacity can be delayed if either one of these contingencies, considered adverse from the standpoint of planning, fails to materialize fully.

Comment 19-123

The high future level of reserves indicated in the Pool plan will, in all probability, never be realized. The present relatively high level of reserve is the result of the economic downturn experienced nationally and its lingering effects which are still prevalent in the northeast sector of the country.

Many of the plants currently in place were authorized and built during the late 1960's and early 1970's, when growth rates demanded the construction of these facilities. In recognition of the need to reduce the cost of energy (presently among the highest in the country), it is necessary to run the least costly existing units to generate electricity to reduce the effect of energy costs on the heavily burdened people. The Roseton and Bowline plants, which are among the most efficient plants in the Pool, thus are an asset to this area.

The implication in the DES that other units can be run in place of Roseton and Bowline does not take into account the economic impact of energy costs on the consumer and, to the extent that this economic burden on the customer is disregarded, does not create the necessary background for the value judgments that need to be made in an environmental impact statement.

Response

The monetary as well as energy costs associated with the loss of generation from the Bowline Point and Roseton stations are discussed in paragraphs 6.73 and 6.75 of the FES. As indicated in these paragraphs, the generation of energy to replace the energy produced by the Bowline Point station would entail a penalty estimated on the basis of 1975 records to be of the order of 10,500 billion Btu, the equivalent of 1.75 million barrels of oil valued at \$26 to \$28 million at 1976 prices. The corresponding figures for the Roseton station, given as 2 million barrels of oil and \$30 million per year in the DES, have been revised in the FES to 2.5 million barrels valued at \$37.5 to \$40 million at 1976 prices.

Comment 19-124

To imply that the simple solution of using gas turbines is a viable alternate to generation with modern steam-electric plants is completely erroneous and contrary to the public interest. Gas turbines are used for peaking purposes and are intended to run for short periods of time to supply short-time peak loads. They are less costly from a capital point of view, but inherently much more expensive because of the fuel used and because of their low efficiency.

The current technology of gas turbines requires that they be fueled with distillate products which are more expensive than the residual oil, coal, or uranium fuel used in large plants. The overall cost of electricity from these turbines, when operated for equivalent time periods, is substantially greater than that of large steam-electric plants. Furthermore, the impact of the heavy consumption of this fuel, for electric generating purposes, on the market price of the product, which may be used for home heating oil, diesel fuel or jet engine fuel, will force the price of these products to rise, or in some instances may produce shortages. This impact on the prices paid by the consumer for many products cannot be dismissed. The supply of this fuel and these products is not geared to large consumption by utilities.

In the case of pumped storage developments, which are also part of the generation expansion plan, the investor-owned utilities are assessing the viability of such developments, on an on-going basis. For some time to come, it will be economic to supply electricity from the present oil fueled plants to run these units. Of course, to the extent that these pumped storage plants exist, it will be best to utilize the most efficient units to pump them, thus increasing the need to run units such as Roseton and Bowline.

Response

There is no intent in the analysis presented in the DES to imply that gas turbines would be used to replace the power generated by the Bowline Point or Roseton stations in the event of operations being suspended at these stations. What is assumed in the analysis (paragraph 6.75 and 6.86 of the FES) is that replacement power would be supplied from all sources controlled by the New York Power Pool. It is assumed that the major portion of the replacement power would be derived from steam-electric facilities which make up the largest part of the generating capability available to the Pool. Since this is likely to involve an increased usage of older, less efficient equipment to meet base load, the energy and cost penalties discussed in response to a previous comment are given in the analysis.

It may be well to note that the economy and reliability of supply associated with the continued, unencumbered operation of the Bowline Point and Roseton generating stations are recognized as benefits in this analysis (Paragraphs 6.06 and 6.78 of the FES). The loss of these benefits is considered as one of the consequences of suspending operations at the two generating stations until closed cycle systems can be installed. This loss is next contrasted to the benefits to the aquatic ecosystem of the Hudson River Estuary expected to result from a temporary suspension of operations. In both the case of the Bowline Point and the Roseton Stations, such benefits to the aquatic ecosystem are taken to be negligible. Accordingly, further investigation into the question of whether a suspension of operations at the two stations would lead to interruptions in customer service is considered unnecessary.

In the context of an indefinite suspension of operations, or abandonment of the Bowline Point and Roseton generating stations, the economic penalties considered in connection with a temporary suspension of operations are inconsequential in comparison to the current worth of the plants and the cost of replacement capacity.

Comment 19-125

Utilities believe, therefore, that from a long-range planning point of view:

1) The availability of actual reserves will, in practice, closely approach the fundamental level required for reliability, and excess reserves will not be available for large purchases.

2) The social implication of increased energy costs to consumers cannot be ignored in the evaluation of alternate electricity supplies to consumers.

3) The relatively efficient and economical Roseton and Bowline plants are cost-justified and must be run for the benefit of the consumers and the improvement of the economic environment.

4) Gas turbines are not a viable alternative for required base-load generation nor is the development of pumped storage facilities.

Response

Detailed responses have been given previously on the need for the Bowline Point and Roseton Generating stations.

Comment 19-126

As to the Roseton Plant and Central Hudson Participation:

Load and capacity data used in the subject DES were largely drawn from the Long-Range Plan presented to the New York Public Service Commission in 1976. This plan is updated annually and each year a formal presentation is made. The 1977 Plan contains further modifications. In this iterative process, Central Hudson has made changes in its load and capacity program, but more importantly, in 1977 has modified its agreement to participate in the ownership of Roseton, responsive to the decline in its anticipated load. It is also important to be aware that as part of the Roseton Agreement, Central Hudson has agreed to purchase seasonal capacity in specified amounts from the other owners of the plant. Roseton generation, therefore, constitutes a substantial share of capacity utilized to serve Central Hudson's customers.

The contention is made on page C-24 of the DES, that Central Hudson could maintain adequate reserve margins through 1980 without Roseton, except in 1978; and that in 1981 and beyond, the contribution from Roseton is required to maintain these reserves.

This contention is erroneous and misleading. A review of Central Hudson's currently approved load and capacity projection shows that, without Roseton, very substantial generation deficiencies will occur in the Central Hudson system. This erroneous conclusion seemingly developed from a lack of understanding by the authors of the DES of the contract purchases from Con Edison and Niagara Mohawk. These purchases are based on purchases of Roseton generation through agreement with the other owners of the Roseton Plant. The elimination of Roseton for use by Central Hudson not only eliminates the use of its share of ownership in the plant, but the use of its committed seasonal purchases from the joint tenants. The sum of these two portions of Roseton generation, if removed from Central Hudson's load and capacity schedule, would produce extremely large deficiencies. It would be expensive for Central Hudson's consumers if Central Hudson had to purchase generation to make up for the loss of generation from Roseton.

Response

An examination of Central Hudson's long-range plans developed subsequently to the 1976 plan (New York Power Pool, 1977; 1978; 1979) confirms the observation made in this comment that capability schedules including net capacity transactions among members of the New York Power Pool are modified periodically in response to updated predictions of peak load and other pertinent factors. Information on the 1976 plan given in Table C-4 in Appendix C of the DES indicates that net capacity transactions make up a considerable portion (20 to 30 percent) of Central Hudson's total capability through the year 1980. The data given applies to the winter months since predictions made at that time showed a somewhat higher peak load occurring in winter than in the preceding summer.

Plans developed in later years show substantive changes from the 1976 plan. The 1979, or latest plan indicates that the Central Hudson system will be a net exporter of power in the winters of 1980-81, 1981-1882 and 1982-1983 and that net purchases of power will make up 14 to 25 percent of Central Hudson's total capability in the summers of 1979 through 1982 (New York Power Pool, 1979). Projection now indicate that the system will be summer peaking although the peak loads experienced each summer will not be vastly greater than the peak load experienced during the following winter.

A part of Central Hudson's summer purchases of capacity will be from the Niagara Mohawk System (New York Power Pool, 1979) and could be derived directly from the Roseton Generating Station. Clearly, this capacity would no longer be available for purchase if the operation of the Roseton station were to be considered adequate for present purposes to assume that replacement capacity would be made available from other sources within the Pool. The major thrust of the present comment appears to be that electrical energy generated by the replacement capacity would be more costly than energy generated by the Roseton facility. This point has been discussed in response to previous comments.

Comment 19-127

Furthermore, the DES implies a similar situation at Bowline. If those units are removed from service, the apparent reserves drop drastically and any opportunity to purchase capacity would only be from old, inefficient units or from gas turbines. Such an alternative, and its drastic economic impact on consumers in the Hudson Valley, is not worthy of suggestion.

Response

Responses to previous comments effectively address the point raised in this comment.

Comment 19-128

Generation planning by Central Hudson, in conformance with the target plan of the Power Pool, allows for the situation which would exist if units were delayed, thus recognizing one of the contingencies described previously. While the potential for excess capacity exists, reserve levels are believed to be within reason and to conform to the Pool concept.

Central Hudson, relying solely on oil fuel, must seek ways to minimize the economic impact of energy costs on its customers by reducing, to the extent possible, the cost of energy. The solution at hand is to operate the Roseton plant for the economic benefit ot its customers and, to the degree that it is able, to sell energy from this plant to other utilities facing higher production costs.

Provision of capacity to meet load requires an analysis of the kind and character of generation facilities and their overall costs. One cannot simply add and subtract numbers on a load and capacity sheet and thereby arrive at a conclusion about overall society benefit.

Therefore, it is believed that the DES, through a misreading of available data, has reached the the erroneous conclusion that Roseton will not be required for the benefit of customers and that substitute capacity may be secured from the Pool until 1981. A correct understanding and evaluation of the data should reach the opposite conclusion.

The correct conclusions are:

1) That Roseton is a more modern and efficient and less costly plant to run than many presently owned by the members of the Power Pool;

2) That Roseton constitutes a substantial portion of the installed capacity of the Pool and not running it will reduce the reliability of the Pool;

3) That Roseton capacity forms a large portion of generation available to Central Hudson and, in the absence of Roseton capacity, Central Hudson would be forced to purchase large blocks of capacity and energy;

4) That substitute capacity would be expensive relative to the operation of Roseton and would be a substantial economic burden on the consumers of the Hudson Valley;

5) That Roseton capacity is some of the least expensive capacity owned by Con Edison and must be run for its account to alleviate the costs of electricity in the metropolitan area;

6) That Roseton capacity and operation produces socio-economic benefits to a broad population and is particulary helpful to the customers of Central Hudson; and because of its relatively lower fuel cost, Roseton should be run as much as economically possible to maximize its benefits.

Response

These conclusions essentially summarize the comments made previously in connection with the need for the Roseton station. No further response is given here.

Comment 19-129

As to the Bowline Plant and Orange and Rockland Participation;

In Appendix C, the Corps has superficially developed charts C-6 and C-7 showing Orange and Rockland, Central Hudson and Con Edison's capacity and reserve generation with and without Bowline and Roseton capacity. These incorrect tables cannot be used when reviewing the present capability of the companies. In Table C-7, for example, the Corps indicates that Bowline accounted for 53.5% of the total energy of the Orange and Rockland system in 1975. This is far in excess of the percentage of the total Orange and Rockland generating capability represented by Bowline capacity. In 1975, Bowline generation consisted of 38% of the Orange and Rockland installed and contracted capacity. Thus, Table C-7 clearly shows that the generation from Bowline for the Orange and Rockland system is considerably in excess of the Bowline percentage of capability. Table C-6 is a superficial compilation which ignores the fact that the Bowline generation (in megawatt hours) to the Orange and Rockland system is considerably more than Bowline's percentage of capacity for the Orange and Rockland system. This indicates that Bowline is a base loaded, highly efficient generation source for Orange and Rockland, and that it cannot be simply ignored and deleted from Orange and Rockland capability without serious economic and electrical consequences.

Response

Tables C-6 and C-8 (not Table C-7) in Appendix C of the DES provide information on the reserve margins of the contribution of the Bowline Point and Roseton generating stations. The conclusions drawn from this information and set forth in Chapter 6 and Appendix C of the DEIS are that Orange and Rockland would be unable to maintain adequate reserves over the decade 1976 to 1985 without the Bowline Point Station, as would Central Hudson and Niagara Mohawk without the Roseton station. On the other hand, reserve margins in the larger Con Edison system as well as the New York Power Pool evidently could be maintained at acceptable levels over the same period with the loss of either the Bowline Point or the Roseton stations. It may be well to note that minor corrections have been made in the third paragraph of page C-24 of the FES to give a more accurate representation of the data contained in Table C-8.

Specific conclusions drawn from Table C-7 which relates to the Bowline Point Generating Station, are set forth in the first paragraph on page C-24 of the DES. Among these is the statement that in 1975, energy generated by the Bowline Point station represented 53.5 percent of the total energy generated by the Orange and Rockland System while capacity derived from the Bowline Point station represented 39 percent of the systems total capability and 44 percent of its base load capability

As indicated in responses to previous comments, there is no explicit statement in the analysis nor any intent to imply that the operation of the Bowline Point station could be suspended without economic penalty. With respect to interruptions in customer service, it is assumed in the analysis that resources available to the New York Power Pool would be made available to avert serious consequences.

Comment 19-130

The substitution of alternate sources of generation to replace prime energy that is suggested here and elsewhere in the DES (Chapter 6) would have substantial economic impacts on Orange and Rockland's customers. The fact is that the production cost of Bowline generation is the lowest in Orange and Rockland's system (after purchase of a small megawatt increment from the Fitzpatrick Nuclear Plant). Therefore, Bowline runs first and longest and would be the last to be taken off in a production operation. Any suggested operating mode of "last on, first off' would result in unjustifiable cost penalties to Orange and Rockland's customers.

Response

The "last-on-first-off" mode of operation of the Bowline Point Generating Station is considered in the context of possible restrictions that might be imposed on the operation of the station. For reasons stated in the DES, it is impossible, at present, to estimate with any degree of certainty the net advantages that the aquatic ecosystem would derive from restrictions of this type. As indicated, there would be monetary and energy penalties attendant to restrictions on the operation of the generating station.

Comment 19-131

The development of Tables C-6 and C-8 completely ignores the fact that each company has different daily, weekly, monthly and annual load factors; that each company has varied components of existing generation; that all companies are not allowed to burn oil with the same sulfur content; that each company has varied incremental production costs; and that each company has varied generating unit minimum load constraints due to indivudual system conditions. The only appropriate way to evaluate alternate generation expansion plans is through the systematic analysis of the entire electric system and sensible alternate plans.

Response

Tables C-6 and C-8 constitute only a part of the analysis of the need for the Bowline Point and Roseton Generating Stations. Variations in load and other pertinent factors are considered to the extent necessary to characterize (1) the benefits associated with the continued operation of the stations, (2) the costs associated with a suspension of operation of either station and (3) the benefits to the aquatic ecosystem of the Hudson River Estuary stemming from the expansion of operation of the stations. As discussed in previous comments, these benefits to the aquatic ecosystem, referred from the analysis related to striped bass are taken to be negligible if the suspension is temporary and small if the effects of a permanent suspension, or abandoment, of the stations are compared with the effects of operating the stations with closed cycle cooling.

Comment 19-132

The correct conclusions are:

1) It is totally untrue that the simple elimination of Bowline and Roseton from the capacity of the companies involved has a negligible effect on their capacity and energy capabilities and their ability to meet their loads.

2) The proposed elimination of Bowline and Roseton from the capacity of the companies involved is a gross oversimplification and ignores the fact that these plants are base loaded, low cost generation and that the elimination of their capacity would have a major impact on the capacity of the utilities involved.

3) The installation of gas turbines in the magnitudes suggested would not be an economic alternative to continued operation of Bowline for Orange and Rockland. Orange and Rockland has developed a generation expansion plan which allows for the installation of some gas turbine capacity in later years to meet deficiencies. This will result in a favorable base/peaking mix. However, the premature installation of gas turbines would preclude the achievement of an economic generation mix and result in economic penalties.

4) Technically, the substitution of peaking generation units for base load units ignores the realities, both of the long-term operating conditions of the two types of units and of system requirements for energy.

Response

These conclusions essentially summerize previous comments and no further response is given here.

Comment 19-133

In addition to the erroneous and misleading conclusions reached by the Corps regarding the planning for and operation of these plants, a comment appears on page C-31 of the DES (last line, double asterisk) concerning the review of sites along the Hudson River by the Power Authority of the State of New York, which concluded that "closed-cycle cooling was found to be a prerequisite in all nine cases".

Utilities do not believe that this "conclusion" should in any way influence the subject case for the following reasons:

1) The studies were not made with the depth of data which has become available in the subject case;

2) The economic parameters utilized by the Power Authority are different from those used by the companies involved in this case; costs incurred by the Power Authority do not have the same impact on customers as do costs of investor-owned utilities.

3) Several of the sites listed are not, by any means, equivalent to Roseton or Bowline in water availability. In fact, some are inland from the River, which in itself precludes the use of once-through cooling. Some are adjacent to shallow water, while others are in the northern reaches of the River where sufficient water does not exist to support once-through cooling.

The insertion of this reference is gratuitous and not germane to this case. Furthermore, the selection of a conclusion out of context is deceptive. This statement seems intended to bias the reader's thinking and should not be part of the environmental impact statement unless all of the facts which dictated the selection of closed-cycle cooling at the proposed Power Authority sites are also presented and shown to be equally applicable to Roseton and Bowline.

Response

The second footnote on page C-31 of the DES has been deleted.

Comment 19-134

Utilities take issue with the degree and nature of contribution of striped bass to the Atlantic fishery suggested on pp. D-9 to D-10 (for more complete information, see McFadden, 1977 at Section 7.10).

Response

This discussion has been modified in the FES to include the results reported by McFadden (1977).

Comment 19-135

Third Paragraph under Air Quality, page S-5 of Appendix E of the DEIS. The cooling towers determined to be appropriate by Central Hudson if cooling towers are for Roseton have a height of 390 feet above base elevation which is approximately 80 percent of the height assumed in the DES analysis. A modeling analysis utilizing the specified tower characteristics as to height and emission rates, conducted for Central Hudson, indicates the potential for ground level, cooling tower induced fogging during about 85 hours in a year when meteorological conditions correspond to those experienced in 1975. This analysis is included in the evidentiary material submitted to EPA Region II on July 11, 1977. A copy of this analysis has been furnished to the Corps (Central Hudson, 1977b).

Response

The correct cooling tower parameters have been used in the FEIS.

Comment 19-136

Last Paragraph under Air Quality, page S-6 of the Appendix E of the FEIS. The DES analysis assumed cooling towers approximately 30 percent higher than those specified for Roseton. In addition, the DES analysis assumed salinity levels (100 - 800 ppm) in the cooling tower makeup water, which are apparently meant to be representative of an average year when the salt front is well south of Roseton. During drought years the salt front moves north of Roseton and River salinities as high as 2,600 ppm have been observed under such conditions. Use of the lower tower height and the higher salinities representative of drought years would result in substantially higher indicated salt deposition rates.

Response

The correct cooling tower parameters and drought year salinities have been used in the FEIS.

Comment 19-137

The circulating water pumps discharge into a 12-ft.-square chamber, not a 9-ft.-square chamber as stated on page 3-8 in Appendix E of the DEIS.

Response

Comment noted.

Comment 19-138

The flow rate should be 1428 cfs, not 1462 cfs as stated on page 3-14 of Appendix E of the DEIS.

Response

Comment noted.

Comment 19-139

The maximum gross generation of Danskammer on oil firing (the case since 1971) is 494 megawatts, not 530 megawatts as stated on page D-1 of Appendix E of the DEIS.

Response

Comment noted.

Comment 19-140

The maximum generation for the total Roseton power plant was approximately 603 gross megawatts (not 110 megawatts as stated on page D-2 of Appendix E of the DEIS) during the entirety of the two simulation periods. However, the assumption that both units were never in operation at the same time is correct.

Response

Comment noted.

NATIONAL AUDUBON SOCIETY

Comment 20-1

Our position is one of total support for the findings and conclusions of Oak Ridge National Laboratory. Their analysis of work done by any number of environmental consulting firms shows that too many of these companies have done inadequate work on the Hudson.

The tragedy here is that the utilities have accepted this work as being the final word. Environmental groups have long maintained that studies done on the river under contract to the utilities were, by their very nature, flawed.

Response

A discussion of the adequacy of the data presented by Utilities regarding entrainment, impingement, and long term impacts to fish populations begins at paragraph 4. . This discussion summarizes the work of Oak Ridge National Laboratory as well as other consultants to the U.S. Environmental Protection Agency.

Comment 20-2

An example of ORNL's thoroughness can be found in their critique of work done by LMS (ORNL/TM-5877/U2 page S-8 Section S.3.5 para. 3). No coalition of environmental organizations could have funded such a study as this (ORNL).

Response

The analysis presented in the document cited, which was reproduced as part of Appendix E in the Draft Environmental Impact Statement, has been superceded by additional analysis carried out by the Oak Ridge National Laboratory and other consultants to the U.S. Environmental Protection Agency since the publication of the Draft EIS. The findings of these new analyses have been incorporated into the Final Environmental Impact Statement.

Comment 20-3

We ask that you support the findings and conclusions of the Oak Ridge National Laboratory.

Response

The Corps of Engineers will consider all relevent information in determining the appropriate decision regarding the points at issue.

NATURAL RESOURCES DEFENSE COUNCIL, INC.

Comment 21-1

The DEIS properly points out that even with sophisticated computer modeling the decision that must be made still revolves around a policy determination of how much risk to the fishery should the public be required to take.

Response

A discussion of the adequacy of the data available for determining the impact to the fishery begins at paragraph 4.

Comment 21-2

The decision, then, comes down to a judgment by the Corps of risk. Will the Corps of Engineers accept the risks presented by the power plants, plus other likely water withdrawals, when alternatives exist which, although costly, are yet well within the financial ability of utilities?

Response

The Corps of Engineers must consider all reasonable alternatives in determining the appropriate decision regarding the intake permits at issue.

Comment 21-3

The Draft EIS's major deficiency is its failure to propose a decision or state a criteria for decision. While we understand this procedure is perhaps sanctioned by CEO guidelines, it is unfortunate that in a case of such complexity the Corps did not present for public comment a proposed decision as well.

Response

An environmental impact statement is not the decision document itself, but rather is a neutral disclosure document of environmental impacts associated with a proposed action. Environmental impacts are then considered along with other relevant factors in the decision process. Corps of Engineer regulations presently prevent the stating of a decision in the impact statement.

Comment 21-4

The Utilities expressly agreed and accepted their construction permits on their agreement that the plants were to be constructed at thier risk and that there should be no consideration in the EIS of the fact that the plants were already constructed. The DEIS cost analysis is therefore incorrect when it shows retrofit costs, shutdown costs, inflationary costs, and the like. The Corps must examine costs solely as if the plants were not built and as if the cooling towers were part of a new plant.

Response

The analysis of impacts must describe the actual costs associated with the construction of cooling towers at Bowline and Roseton. Since such construction would require retrofitting the power plants as now operating, the analyses cannot pretend that such is not the case. It is true, however, that the Utilities accepted the risk that, should cooling towers be required in the future, their costs would be considerably greater.

Comment 21-5

The court order commands a decision for both Bowline Point and Roseton. The Corps cannot delay its decision.

Response

The Corps of Engineers will make a decision in accordance with the schedule required by the court.

Comment 21-6

Because the utilities are vigorously contesting cooling towers at all sites, on legal as well as factual grounds, and because the Corps cannot discount the possibility that the utilities will be successful, the Corps can consider only the worst case in evaluating risk.

Response

A worst case approach has generally been used in the analyses in the FEIS.

Comment 21-7

The action being considered by the Corps is the granting of a permit to allow construction of intake and discharge structures related to two power plants. HRFA does not oppose allowing the necessary construction but vigorously contends that adequate and available means to mitigate the volume of water withdrawals must be imposed.

Response

Comment noted. The Corps of Engineers will consider all relevant information in making its decision.

Comment 21-8

There is a substantial risk that the adult striped bass population will be reduced by more than half if Hudson River plants continue to operate as they do at present.

Response

Material submitted by the U.S. Environmental Protection Agency as testimony in the on-going adjudicatory hearings indicates that available data are generally inadequate to predict long-term impacts to adult fish populations (see discussion beginning at paragraph 4.).

Comment 21-9

Although there are huge gaps in the knowledge of effects upon other species, the available information is highly suggestive that the harm to certain species will be even greater than the harm to striped bass.

Response

See response to comment 21-8.

Comment 21-10

Compensation by the fishery has not been shown and, as evaluated by Oak Ridge, could not possibly be of the magnitude suggested by the utilities. Furthermore, there is no evidence that other means of mitigating the harm to the fishery are effective.

Response

Compensation has not been clearly demonstrated in the fish populations of the Hudson River (see paragraph 4.). Other means of reducing entrainment and impingement are possible, but studies of their effectiveness have not been carried out on the Hudson River (see Chapter 6).

Comment 21-11

The DEIS does not clearly state what is the proposed action for which it has been drafted.

Response

The actions available to the Corps of Engineers are (1) to retain unaltered the present permit and related conditions, (2) modify the permit through the imposition of additional conditions, (3) suspend the permit, or (4) revoke the permit (see paragraph 6.01).

Comment 21-12

It is one thing to ask, as the DEIS does, whether it is justified to compel the utilities to spend $100 million each for cooling towers. It is quite another to ask, in connection with allowing the construction of of beneficial power-generating plants costing $250 million each (with a replacement value of $1 billion each), whether the Corps is justified in requiring the owners to minimize environmental risks by restricting the volume of water intakes. The manner in which the issue is phrased in the the DEIS suggests that the only concern is additional restrictions rather than minimizing impacts in connection with granting the overall application.

Response

The duty of the Corps of Engineers is to evaluate the impacts associated with the operation of the Bowline Point and Roseton Generating Stations in conjunction with other power plants on the Hudson River. The decision of the Corps must be that which best serves the public interest. The options available to the Corps in deciding on the appropriate action to take on the permit request for placing of cooling water intake structures in navigable waters have been given above in the response to Comment 21-11.

Comment 21-13

The need to minimize withdrawals of water is established in the showing of the severe environmental risks in the DEIS. This is so even with the DEIS's failure to quantify even minimally the risk to the fishery from once-through cooling.

Response

The Corps of Engineers disagrees that no attempt has been made in the EIS to quantify the risk to the fishery. The difficulty in carrying out such an analysis has been discussed beginning at paragraph 4.

Comment 21-14

The Corps should allow the permit, but condition the construction to limit the water withdrawals in order to minimize the substantial environmental impacts of the impingement, entrainment, and thermal discharge.

Response

Comment noted.

SAVE OUR STRIPERS, INC.

Comment 22-1

Computer modelling: Computers are excellent tools but they only do what the human programmer tells them to do. All model projections should be considered suspect because in most cases the data are from only two years. The model fails to account for peaks and valleys in the cycles and in most cases the model did not take into consideration all the plants that affect the species.

Response

The Utilities Real-Time Life Cycle model and the U.S. Environmental Protection Agency Empirical Transport Model include the effect of all power plants that have the largest potential for effecting striped bass eggs, larvae, and juveniles. The utilities model incorporates stochiastic model events into the model. A discussion of the usefulness of these modeling efforts begins at paragraph 4.

Comment 22-2

The two major problems are Indian Point and Bowline. Insisting that these two have closed-cycle cooling systems would solve the bulk of the problem.

Response

Comment noted.

Comment 22-3

The independently sought data points in the direction of closed cycle cooling in one form or another. Dry cooling seems to be impractical for large plants, but evaporative systems would seem to do well. We believe that on the strength of existing evidence some form of closed-cycle cooling system for Bowline and Indian Point is absolutely necessary.

Response

The environmental impacts of use of evaporative cooling towers is discussed in the FES beginning at paragraph 4.85 .

Comment 22-4

As much thought should be given to the protection of other species and habitats in the Hudson as you have for the striped bass. Sections two and four show that power plants are affecting wetlands, plankton productivity, and other fish such as anchovies which may have an effect on total food supply available for striped bass. (Sections 2-33, 2-56, 2-58, 4-110, 4-57, 4-64, 4-66, etc.)

Response

Total loss of wetland areas from construction of existing power plants is not known, but 60 acres were filled in construction of the Bowline station (see paragraph 4.112 of the FES). Impacts to phytoplankton productivity are expected to be slight (see paragraph 4.163of the FES). Presently available data on impacts to white perch, Atlantic tomcod, American shad, Blueback herring, and shortnose sturgeon are discussed beginning at paragraph 4.173 of the FES.

Comment 22-5

Texas Instruments studies comparing the relative contributions of the Hudson River and Cheasapeake Bay to the Atlantic fishery should not be used as an argument to attempt to dismiss the Hudson River's contribution as unimportant. Chesapeake production has been exceptionally poor since 1970. In this light the Hudson's contribution is of vast importance.

Response

A revised analysis of the contribution of Hudson River striped bass to the Atlantic fishery is given in the FES beginning at paragraph 4.242.

Report ORU81R3

BOWLINE POINT GENERATING STATION IMPINGEMENT SURVIVAL STUDIES, 1975-1978

OVERVIEW REPORT

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CONTENTS

CONTENTS (CONT.)

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (CONT.)

CHAPTER 1: INTRODUCTION

Power plants use large volumes of water for condenser cooling. Many employ once-through cooling systems that involve heat transfer to cooling water which is returned to the source waterbody. Debris and macroorganisms are filtered from cooling water with rotating (traveling) screens at the plant intake. Most traveling screens are 0.953-cm bar mesh and are usually held stationary for various time periods prior to cleaning but can be continuously rotated depending on accumulation of impinged material. Small fish (30-150-mm TL) commonly are among those organisms impinged. The potential for impingement mortality loss and resultant effects on recruitment to adult stocks is an important fisheries resource issue (DeAngelis et al. 1977; Hanson et al. 1977; Van Winkle 1977; Van Winkle et al. 1978). Most published studies dealing with impingement have addressed estimations of the number of fish impinged (Grimes 1975; Mathur et al. 1977), but little information exists in the published literature concerning survival of impinged fish.

The studies described in this report were designed to assess survival of impinged fish and determine the intake screen operating mode which maximized fish survival. The effects of impingement on fish survival were studied in relation to screenwash pressure and hold time between screenwashes. These studies were also used to evaluate the effects of selected physicochemical variables on fish survival following impingement.

The studies presented in this report were conducted during seasons of peak impingement (late fall to early spring) from December 1975 through May 1978. Emphasis was placed on young-of-the-year and yearling (30-150-mm TL) white perch, which were the most abundant taxon (Table 1-1). Less numerous species (striped bass, Atlantic tomcod, blueback herring, rainbow smelt, and hogchoker) were studied when sample size was sufficient. Impingement of fish older than yearlings was so infrequent that sample sizes were insufficient to evaluate survival.

Portions of the data base evaluated in this report have previously been presented in Ecological Analysts, Inc. (1977), Orange and Rockland Utilities (1977), and King et al. (1978). Quality control of the entire data base indicated that minor numerical differences occurred among the various final reports. The corrections to the data are identified in Appendix E. These changes were the result of errors in the original hand tabulation of the data prior to computerization of the final data base.

TABLE 1-1 THE FIVE MOST ABUNDANT TAXA IN IMPINGEMENT COLLECTIONS AT THE BOWLINE POINT PLANT, 1973-1977[a]

	Year[b]				
Species	1973	1974	1975	1976	1977
White perch	59.2	70.0	66.9	86.2	62.0
Striped bass	5.9	15.8	12.1	6.9	8.5
Rainbow smelt	--[c]	2.4	14.6	3.7	14.8
Blueback herring	15.1	3.6	2.9	0.8	--
Gizzard shad	--	--	1.1	0.7	10.3
Alewife	3.4	4.6	--	--	--
Atlantic tomcod	10.8	--	--	--	1.1
Others[d]	5.6	3.6	2.4	1.7	3.3

(a) Adapted from LMS 1978, 1977, 1976, 1975, and 1974.

(b) Data presented for period during which survival studies were conducted, January through April and November and December.

(c) Dash indicates less than 1.0 percent.

(d) No species included in this category constituted more than 1.0 percent of the collection.

CHAPTER 2: SUMMARY

Impingement studies conducted at the Bowline Point Generating Station from late 1975 through early 1978 indicated that initial survival of white perch, striped bass, Atlantic tomcod, and hogchoker was between 85.1 and 100 percent. Initial survival of white perch and striped bass generally increased with decreasing time between screen washes; the effect of screenwash mode was more pronounced for blueback herring and rainbow smelt. Atlantic tomcod survival was more than 98 percent for all operational modes.

Extended survival of white perch and striped bass exhibited a strong influence of season as well as a significant effect of screen operation mode, similar to that noted for initial survival. Survival for both species was lowest during winter and highest during fall; during early spring, survival increased over the winter low. This depression of survival during winter appeared to be related to the additional stress of low water temperatures. Few rainbow smelt (1.5-3.8 percent) and no blueback herring survived through the 108-hour holding period.

Control tests indicated that mortality related to handling and collection increased with duration of exposure to the collection net. It was apparent that a considerable portion of the mortality observed among impinged fish during the holding period resulted from collection, handling, and holding.

Consequently, in order to assess the impact of impingement at the Bowline Point Plant it is necessary to adjust the extended survival values to account for control mortality and latent impingement effects. Estimated impingement survival for white perch (expressed as a percentage) under various intake traveling screen modes, was:

Season	Continuous Screenwash	Intermittent Screenwash (4-hr hold)
Fall	97.4	13.9
Winter	44.7	4.0
Spring	77.9	21.0

It is expected that striped bass impingement survival would be similar to that for white perch.

The extended survival of impinged fish was influenced by water temperature and conductivity. The presence of higher conductivity values in the vicinity of Bowline Point enhanced survival of white perch and striped bass; however, this enhancement was suppressed at low temperatures. Below 4.5 C survival was directly related to temperature, and below 3.5 C survival did not exceed 30 percent for impinged or sampling control fish.

CHAPTER 3: SITE DESCRIPTION

3.1 THE WATERBODY

The Bowline Point Generating Station is situated on the west bank of the Hudson River estuary, approximately 60 km north of the southern tip of Manhattan. The river in this area is at its maximum width and characterized by a relatively narrow shallow channel and wide shoal areas bordering both shores.

Flow rates in the estuary (5,000 m^3/sec) are controlled predominantly by the tides. Salinity in the vicinity of the plant generally ranges from near zero to approximately 8 ppt. Seasonal trends are primarily controlled by the freshwater discharge from the watershed, which ranges from about 175 m^3/sec in summer to 1,750 m^3/sec in spring. During perods of low runoff, the salinity in the vicinity of the plant may fluctuate rapidly in response to the tide.

3.2 THE PLANT

The plant consists of two oil- or gas-fired steam electric units, each with a net generating capability rating of 600 MWe and a maximum gross capability of 622 MWe. Unit 1 began commercial operation in September 1972 and Unit 2 began commercial operation in May 1974.

Each unit has a separate once-through cooling water system that transfers waste heat from the condensers to the Hudson River. Water for condenser cooling is withdrawn from a small embayment of the estuary known as Bowline Pond and is returned directly to the Hudson River through an offshore jet diffuser (Figure 3-1). Bowline Pond has a surface area of 490,000 m^2 and is generally shallow, with a maximum depth of 12-15 m.

The cooling water intake structure is 43 m wide, about 8 m deep at mean water level, and consists of six bays, three for each unit. Each bay is approximately 5 m wide and equipped with a vertical bar trash rack, a vertical traveling screen, and a 700-m^3/min circulating water pump. The three circulating pumps for each unit can be operated individually or in combination:

Number of Pumps Operating	Total Flow[(a)] m^3/sec (gpm)	Intake Approach Velocity m/sec (fps)
3	24.2 (384,000)	0.23 (0.77)
2	20.0 (316,000)	0.18 (0.59)
2 (throttled)	16.2 (257,000)	0.15 (0.49)

(a) At mean water elevation.

Typically, two pumps are operated per unit at either throttled (140 x 10^4 m^3/day) or full (172 x 10^4 m^3/day) flow.

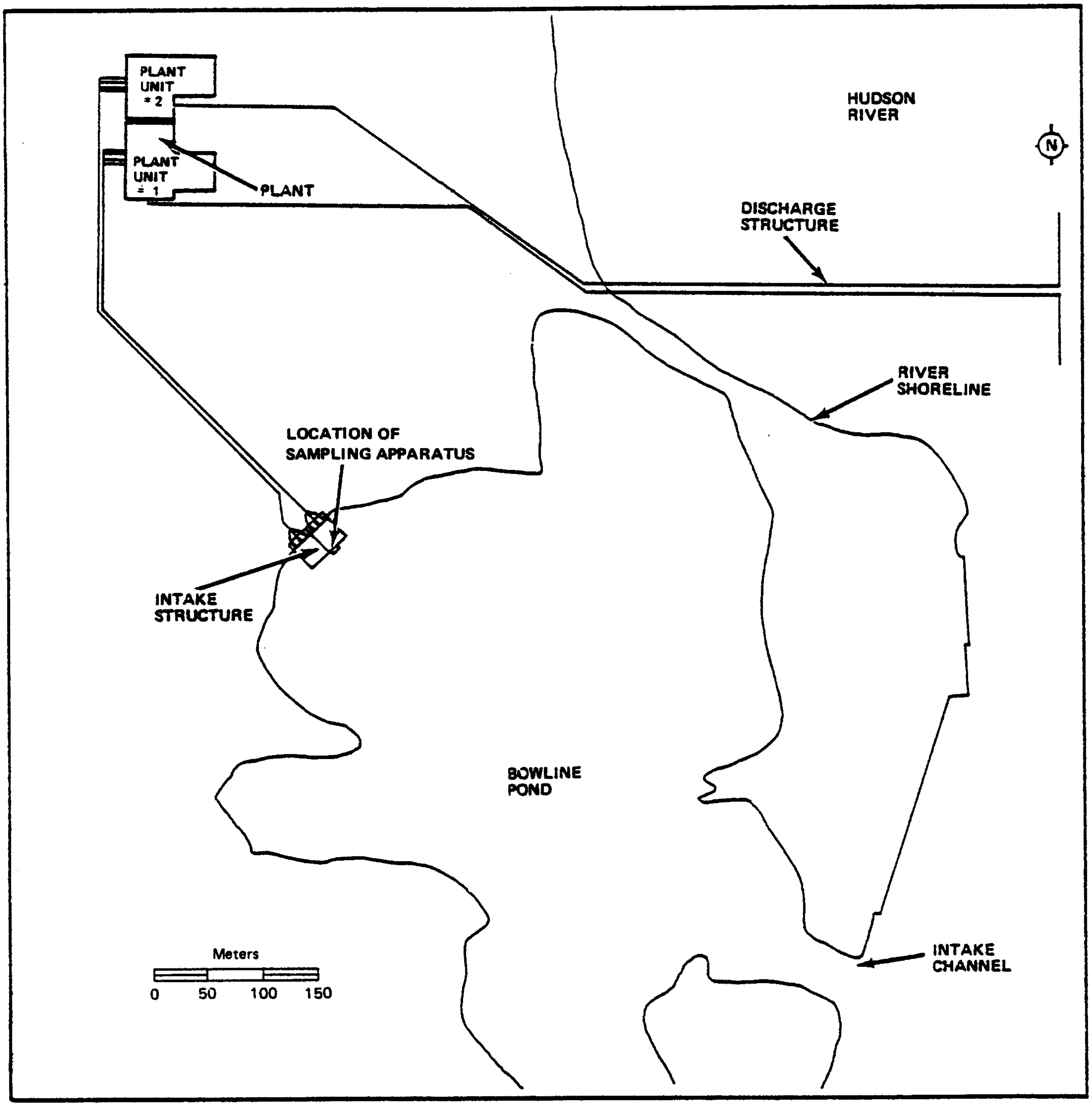

Figure 3-1. Diagram of Bowline Point plant site.

3.3 TRAVELING SCREENS AND FISH COLLECTION SYSTEM

Fish and debris that pass through the bar racks and are impinged on the traveling screen (Figure 3-2) are removed by a pressurized washwater system, rinsed into a sluiceway, and returned to Bowline Pond. During these tests the screens were rotated on a continuous basis or on an intermittent schedule with either a 2-hour or 4-hour hold:

Mode	Duration (minutes)	
	Stationary Hold	Wash Rotation
Continuous	None	Continuous
Intermittent 2-hour	100-110	10-20
Intermittent 4-hour	220	20

The traveling screens are equipped with low-pressure and high-pressure spray headers spaced 30 cm apart vertically on the front face near the upper end of the screen. As the traveling screens rotated, impinged fish and debris were first exposed to the low-pressure spray system operated at 0.7-2.74 kg/cm^2 (10-39 psi). Debris or fish that remain on the traveling screens are subsequently exposed to the high-pressure spray system operated at 2.81-4.22 kg/cm^2 (40-60 psi), to ensure maximum screen cleaning. The high-pressure system can also be operated independently. The washwater sluiceway slopes into the impingement collection pit (Figure 3-3). A baffle system in the collection pit retains large pieces of debris while organisms are returned to the pond through the screenwash discharge pipe.

The impingement collection pit was the primary collection area used for impingement survival studies. In order to retain impinged organisms, the collection pit was fitted with a 9.5-mm-bar-mesh steel basket. This basket provided support for the collection apparatus, which consisted of two knotless nylon bag nets (1.3-cm-bar mesh) suspended between two aluminum poles and a frame, which fit tightly into the steel mesh basket.

3.4 EXTENDED HOLDING FACILITY

Impinged and control fish were observed for extended survival in an ambient water flow-through facility supplied with water from Bowline Pond. The flow provided water at a rate equal to the volume of the holding facility every 6 minutes. A series of tanks with standpipe drains were set up either in the lab or outside, depending on the season and weather conditions. The tanks served as receptacles for flow-through holding containers (60 x 45 x 30 cm) in which the side panels were replaced with 1.5-mm nylon mesh screens to permit circulation of water. In an attempt to reduce holding stress during clupeid studies, these fish were placed in 382-liter cylindrical tanks (90 cm diameter x 60 cm deep). These tanks had darkened interiors, were equipped with stand-pipe drains, and were supplied with ambient water to establish a directed circular flow. All species collected were held in the cylindrical tanks in 1978.

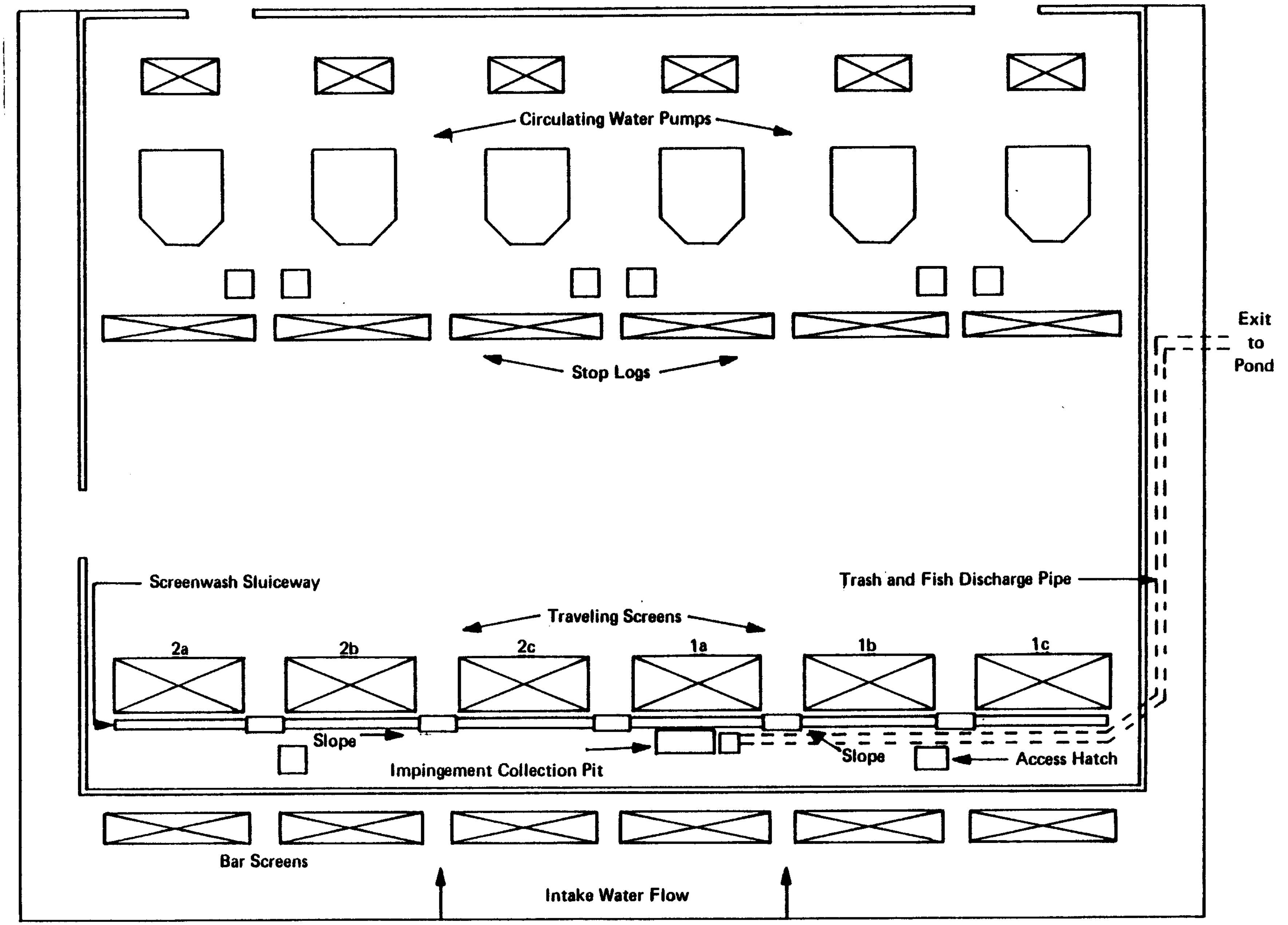

Figure 3-2. Schematic of the Bowline Point plant intake structure.

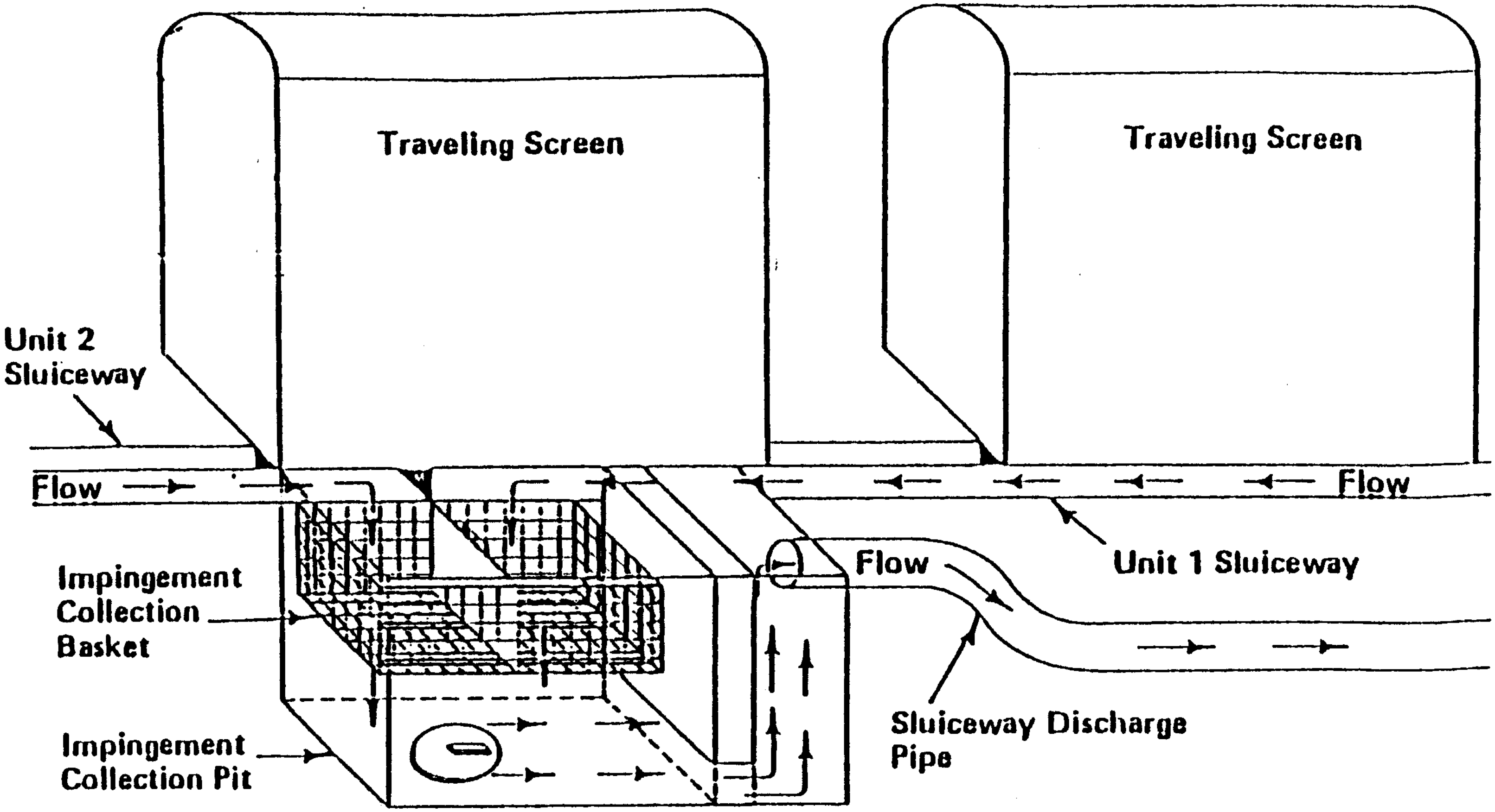

Figure 3-3. Washwater discharge sampling system with collection apparatus in place at the Bowline Point plant intake.

CHAPTER 4: METHODS AND MATERIALS

The field procedures used were generally similar throughout the entire 4-year study and are described below. However, occasional modifications in sampling and holding procedures were instituted as a result of changes in the study objectives or in an effort to reduce the effects of collection, handling, and holding stress. These modifications are summarized in Appendix A.

4.1 SCREEN SURVIVAL COLLECTION PROCEDURES

Prior to each sampling effort, the water level in the collection pit was adjusted to fill, but not overflow, the steel collection basket and collection nets. Screens were cleaned with a 30-minute prewash and all fish and debris were discarded. Following the prewash collection, empty collection nets were inserted in the steel basket and either the screenhold period for intermittent operation or the wash for continuous operation was initiated. During continuous screenwash samples, the collection nets were emptied and replaced at 30-minute intervals depending on the number of fish and amount of debris present. For intermittent wash modes, the nets were removed at the end of the 10- or 20-minute wash period.

Fish were sorted at the intake immediately after the collection nets were removed from the screen basket. The nets were placed in a water-filled trough near the collection pit. All live and stunned* fish were removed, identified, and placed in 81-liter transport containers filled with ambient water. Dead fish were then identified, measured, and preserved.

Live and stunned fish were transported to the holding facility and transferred into separate screened flow-through holding containers. The number of fish held in an individual container depended on the size of the fish: from 20 to 35 young of the year (Table 4-1) or from 5 to 15 yearling and adults. After the fish were sorted, the holding containers were partially covered to reduce unnecessary disturbances to the fish.

Fish were observed at intervals after collection to evaluate latent effects associated with impingement. Between December 1975 and November 1976 the observations were made at 6, 12, 24, 48, and 96 hours; beginning in December 1976 they were made at 6, 12, 36, 60, and 108 hours. An observation made at 96 or 108 hours will be referred to as the 108-hour observation wherever pooled data are used in this report.** All dead fish observed at each observation interval and any fish alive at the final observation were removed, identified, measured, and preserved.

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* Live: swimming vigorously, no orientation problems;
Stunned: swimming abnormally, struggling, no movement except in response to gentle probing;
Dead: no vital life signs; no body or opercular movement, no response to gentle probing.

** The survival curves generally leveled off between 36 and 60 hours, and differences in survival between 96 hours and 108 hours were negligible (see Section 6.2).

TABLE 4-1 LENGTH GROUPS AND YEAR CLASS CATEGORIES USED DURING IMPINGEMENT STUDIES AT THE BOWLINE POINT PLANT, 1975-1978

Species	Period	Year Class Category[(a)]	Length Group (mm)
White perch	NOV-DEC	YOY	30-123
		Y+	>123
	JAN-MAY	Y	<123
		Y+	>123
Striped bass	NOV-DEC	YOY	<125
		Y+	>125
	JAN-MAY	Y	<125
		Y+	>125
Atlantic tomcod	NOV-APR	A	> 77
Blueback herring	OCT-DEC	YOY	< 74
		Y	74-115
Alewife	OCT-DEC	YOY	< 90
		Y	90-160
Rainbow smelt	FEB-APR	Y	<100
		A	>100

(a) YOY = young of the year; Y = yearling; Y+ = yearling and older; A = adult.

Plant operating conditions, tide conditions, and water physicochemical parameters were monitored periodically throughout each sampling effort. Plant and tidal data recorded include number of operating circulator pumps and traveling screens, screenwash pressures, tide height, and tide stage. Water chemical parameters were obtained from Bowline Pond (middepth), near the middle of the Unit 1 portion of the intake structure, and in the holding facility for each extended survival observation. Temperature, dissolved oxygen, pH, and conductivity were monitored using a Martek MK-V. The back-up units used if the Martek malfunctioned were the YSI S-C-T Model 33 (temperature and conductivity), the Port-Matic Model ILI75 (pH), and the Winkler titration (dissolved oxygen).

4.2 CONTROL TEST PROCEDURES

Control tests were conducted to determine the mortality associated with sample collection and holding stresses. Fish for use in control tests were collected with trawls (1-2 minute duration), and from the intake screens (when severe ice conditions prevented river collections). To reduce the effects of collection and handling stress, control fish were maintained in 2-4 ppt saline water for 2-4 hours following collection. Fish used as controls were obtained 48-72 hours prior to impingement survival sampling.

Control test runs were generally conducted before the start of a series of impingement sample collections. To prevent impinged fish and debris from entering the impingement collection pit during the control tests, knotless nylon bag nets (1.5-mm bar mesh) were used to block the sluiceway on each side of the impingement collection pit. A piece of hardware cloth (6-mm) fit across the flow of water entering the impingement collection pit to further filter the screenwash water.

Immediately before each control run, 25-50 fish were transferred from the holding facilities to the impingement collection area. During peak impingement in 1975 and 1976, these control fish were given a caudal fin clip* to differentiate them from impinged fish not retained by the sluiceway barrier nets.

The fish were gently introduced to the screenwash flow entering the impingement collection pit to initiate a sample and were held in the collection net for various time intervals up to 30 minutes to evaluate the effects of handling and collection with respect to exposure time. Control tests were run for 1, 10, 15, 20, and 30 minutes, which reflected the range of durations that impinged fish may be subjected to the collection gear during normal screen operation. At the termination of a control sample, the collection net was removed and placed in the sorting trough and a second collection net was placed in the impingement collection pit. The sluiceway barrier nets were then removed; fish collected in the barrier nets were not held for survival observation. Sorting, holding, and monitoring procedures for control fish were the same as those used for impinged fish.

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* A small portion of the ventral lobe of the caudal fin was removed with a paper hole punch.

Holding control tests were conducted periodically to evaluate the effect of the holding facility on survival. Holding control fish, numbering from 25 to 50, were transferred to flow-through sample containers to be observed for extended survival at the same intervals as impinged and control fish.

4.3 QUALITY ASSURANCE

Quality assurance measures included (1) onsite training, and (2) use of standard operating procedures. During sampling, the crew used a field notebook package that included standard operating procedures for the impingement survival studies. A reference collection and various dichotomous fish identification keys were also available to aid in the identification of impinged fish. Color-coded labels were used for extended survival observations to clearly distinguish holding containers and jars. Measuring boards and size classification guidelines were used to classify test fish into length groups.

At the termination of the extended survival observations, each jar of preserved fish was checked to ensure that the label and contents were the same as the data recorded on the corresponding data sheet.

4.4 ANALYTICAL METHODOLOGY

In order to evaluate the effects of screenwash mode on fish survival, the data were partitioned into seasonal groups based on previous survival data collected by LMS (1976) and graphical inspection of the EA data base. The winter season, when survival appeared to be lower, was separated from late fall and spring. The breakdown was as follows:

Month Group	Season	Characteristic
November-December	Late fall	Water temperature decreasing
January-February	Winter	Water temperature stable and low
March-April	Spring	Water temperature increasing

Within each seasonal grouping, weighted mean survival for the various screenwash modes was calculated by pooling the individual samples for each mode. The following equations were used to calculate initial and extended survival:

$$\text{initial survival} = \frac{\text{no. live} + \text{no. stunned}}{\text{no. live} + \text{no. stunned} + \text{no. dead}}$$

and

$$\text{extended survival} = \frac{\text{no. live}^{*} + \text{no. stunned}^{*}}{\text{initial no. live} + \text{initial no. stunned}} .$$

The chi-square test (Fleiss 1973, pp. 92-96) was used to detect significant differences between survival proportions. This test was used to evaluate

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* Number at time of observation.

survival with respect to screenwash pressure, screenwash mode, season, and duration of control collection hold. The chi-square test initially applied to the data was calculated according to the following equation (Fleiss 1973, p. 93):

$$\chi^2 = \frac{1}{\bar{p}\,q} \sum_{i=1}^{m} n_i \cdot (p_i - \bar{p})^2$$

When the calculated χ^2 value was significant at $\alpha = 0.05$, the data were examined for trends in survival and partitioned into two groups for further analysis. The test for differences between groups was calculated as follows (Fleiss 1973, p. 94):

$$\chi^2 = \frac{1}{\bar{p}\,\bar{q}} \frac{n_1\, n_2}{n_{..}} (\bar{p}_1 - \bar{p}_2)^2$$

where

p_i = proportion surviving in group i
n_i = total number of fish tested in group i
$n_{..}$ = total number of fish tested
$\bar{p} = \dfrac{\text{(number surviving in group 1) + (number surviving in group 2)}}{n_{..}}$
$\bar{q} = 1 - \bar{p}$.

To separate mortality which results from the stress of impingement and mortality from collection and observation, it is necessary to use the control data to adjust survival of fish collected from the intake screens. Since field observations support the assumption that impinged fish enter the collection net evenly throughout the 30-minute collection period, the exposure duration for the "average" fish in the collection net is 15 minutes. However, control fish were placed in the collection basket and exposed for discrete durations between 0 and 30 minutes. The average collection and observation effect was, therefore, predicted from the 0, 1, 15, 20, and 30 minute control data by non-linear regression (Dixon and Brown 1977). The regression (BMD-P3R) predicts the parameters (a and b) of the non-linear function by least-squares using a Gauss-Newton iterative algorithm. Control survival (P_c) was then estimated from the following equation:

$$P_c = \frac{e^{a + bt}}{1 + e^{a + bt}}$$

where t = duration of exposure = 15 minutes.

The variance of the predicted control survival was calculated using the covariance matrix (C) for the function:

$$\mathrm{Var}\,(P_c) = d'\,C\,d$$

where

$$d = \left(\frac{A}{B}\right)$$

$$A = \frac{e^{a + bt}}{\left(1 + e^{a + bt}\right)^2}$$

$$B = \frac{te^{a + bt}}{\left(1 + e^{a + bt}\right)^2}$$

Extended survival data were analyzed graphically to determine whether live fish collected from the intake screens exhibit any latent mortality as a result of impingement and the temporal extent of those latent effects. A qualitative evaluation of the latent effects of impingement was made by comparing the survival curves for control and impinged fish.

Survival of impinged white perch (experimental, P_E) was adjusted for mortality associated with collection, handling, and holding, assuming that the effect of these sources of stress were additive:

$$S_i = \frac{P_E}{P_C}$$

where S_i = proportion surviving impingement.

Based on the analysis of the latent effects of impingement, this adjustment was made for 108-hour survival:

$$\text{proportion surviving} = \frac{\text{no. alive (108 hours)}}{\text{no. alive (initial)} + \text{no. dead (initial)}}.$$

The standard error of S_i was calculated by means of the following equation (Fleiss 1973, p. 69) in order to provide a range around the impingement survival estimate:

$$\text{standard error} = \frac{1}{P_C}\left[\frac{P_E\,(1 - P_E)}{n_E} + S_i^2\ \mathrm{Var}\ (P_C)\right]^{\frac{1}{2}}.$$

While this equation gives the variation around the impingement estimate, it does not account for variation in survival observed among individual samples.

Effects of conductivity, water temperature, and air temperature on impinged fish survival were examined. Mean conductivity and mean water temperature were calculated for individual collections by averaging the five measurements made through the latent effects holding period. Air temperatures at the time of collection were provided by Orange and Rockland Utilities from the plant site meteorological tower (elevation 10 m). It was observed that 108-hour white perch survival:

$$\text{proportion surviving (108 hours)} = \frac{\text{no. live + no. stunned}}{\text{no. live + no. stunned + no. dead}}$$

was consistently lower than 30 percent at water temperatures less than 3.5 C. Graphical analysis of survival data indicated a probable linear relationship with temperatures up to 4.5 C, so the survival data were grouped into categories of either greater than or less than 4.5 C. The relationship of survival at 108 hours to these three variables was examined using multiple linear regression analysis. Samples composed of 10 or less fish were excluded from the analyses to reduce variability introduced by small sample sizes.

CHAPTER 5: RESULTS

5.1 INTRODUCTION

Survival studies conducted in 1974 and early 1975 demonstrated the potential for high initial survival of white perch, striped bass, Atlantic tomcod, and hogchoker (71.8-99.1 percent) (Table 5-1) and that there was an apparent difference in survival between seasons (LMS 1976). Highest survival occurred in the late fall (November-December) and spring (March-April). Survival of Alosa sp. was low (11.7-22.7 percent). A few tests were conducted in early 1975 in which impinged fish were held for time periods up to 156 hours after collection. These tests showed apparent survival for extended periods following impingement (LMS 1976).

Ecological Analysts conducted studies between December 1975 and May 1978 to measure the survival of the most abundant taxa impinged at the Bowline Point plant (white perch, striped bass, Atlantic tomcod, rainbow smelt, clupeids, and hogchoker). These studies were designed to determine the wash pressure and hold period between washes which would provide optimal conditions for fish survival.

After graphical examination of the data indicated that survival was similar during particular month groups across all years, the data for most analyses were combined over the 4 years of the study. Data are provided in a more detailed form in the Appendixes as follows:

1. Appendix B - Initial and 108-hour survival
2. Appendix C - Extended survival at each observation period
3. Appendix D - Data sets used for physicochemical effects evaluation.

Studies conducted between November 1976 and April 1977 evaluated the effects of the high- and low-pressure screenwash system on fish survival. King et al. (1978) reported that survival of white perch and striped bass under the low-pressure wash (0.70 to 1.41 kg/cm^2 [10-20 psi]) was not significantly greater than with the high-pressure system alone (2.11 to 3.51 kg/cm^2 [30-50 psi]).* This result was attributed to the following factors:

1. the low-pressure screenwash system did not effectively remove fish from the traveling screens prior to their contact with the high pressure system, or

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* The criterion originally employed by King et al. (1978) to determine a low- or high-pressure test was based on operation of the high-pressure system alone or in conjunction with the low-pressure system. However, later examination of the data indicated that, at times, the high-pressure system actually operated in the low-pressure range (less than 2.81 kg/cm^2 [40 psi]). Consequently, the survival data were reevaluated according to pressure criteria where low pressure was 0.70 to 2.74 kg/cm^2 (10-39 psi) and high pressure was greater than 2.74 kg/cm^2 (>39 psi). In general, operation of the low-pressure wash system did not result in significantly ($\alpha = 0.05$) greater initial or extended survival for white perch and striped bass.

TABLE 5-1 INITIAL IMPINGEMENT SURVIVAL FOR YOUNG-OF-THE-YEAR AND YEARLING FISH DURING STUDIES CONDUCTED AT THE BOWLINE POINT PLANT, 1974[a]

	Striped Bass		White Perch		Atlantic Tomcod		Alosa Spp.		Hogchocker	
	No.	Proportion Surviving	No.	Proportion Surviving	No.	Proportion Surviving	No.	Proportion Surviving	No.	Proportion Surviving
NOV-DEC	626	0.866	2,683	0.789	100	0.990	674	0.227	41	0.903
JAN-FEB	1,083	0.388	7,348	0.259	31	0.387	967	0.117	3	0
MAR-APR	5,117	0.768	11,429	0.718	25	0.840	173	0.167	11	0.727
MAY-OCT	197	0.457	493	0.454	578	0.610	1,016	0.121	774	0.991

(a) Adapted from LMS 1976, pp. VIII-5 - VIII-10.

2. both pressures tested were sufficiently low to permit similar survival.

Therefore, the data collected during the evaluation of the high- and low-pressure system (November 1976 through April 1977) were pooled in subsequent analyses.

Attempts were made to evaluate the effects of the screenwash discharge pipe; however, extended survival observations of control fish release in the pipe indicated that a satisfactory sampling technique had not been developed. Based on studies of fish transport through pipes conducted by Taft et al. (1977), it was concluded that significant additional fish mortality at the Bowline Point plant was not likely to occur from transit through the discharge pipe (King et al. 1978).

5.2 INITIAL SURVIVAL

5.2.1 Impinged Fish

Survival of fish exposed to the intake screens for various time intervals was evaluated. White perch survival ranged from 85.1 to 97.8 percent (Table 5-2), and a significant ($\alpha = 0.05$) decrease in survival with increasing screenhold time was observed (Table 5-3). Survival of striped bass ranged from 84.6 to 100 percent and showed a similar response to screenhold time. Blueback herring (36.7-79.5 percent) and rainbow smelt (66.4-94.3 percent) demonstrated a similar trend. For these two species lower survival was noted for the hold modes (Table 5-2) than was observed for white perch and striped bass. Initial survival of Atlantic tomcod and hogchoker was usually 100 percent for all three screenwash modes.

Initial survival values did not exhibit consistent seasonal effects: whereas striped bass survival was generally lowest during winter, white perch survival was similar for all three seasons within each operational mode (Table 5-3).

The proportion of white perch classified initially as stunned varied with both season and screen operation mode (Table 5-4). The proportion of stunned collected during continuous operation was highest (69.8 percent) in the January and February time period. There was also an increase in stunning associated with increased time between screen washes.

5.2.2 Control Fish

Control tests were conducted to evaluate collection and handling effects. Survival of white perch and striped bass in these tests was 93.8-100 percent (Table 5-5). Survival was generally 100 percent for all hold durations from 1 to 30 minutes.

5.3 EXTENDED SURVIVAL

Impinged fish were observed for 108 hours after collection to evaluate the extended effects of impingement. Control tests were conducted to quantify the level of mortality associated with collection, handling, and holding that is inherent in extended impingement survival estimates.

TABLE 5-2 SURVIVAL OF FISH IMPINGED AT THE BOWLINE POINT PLANT AS A FUNCTION OF SEASON AND SCREEN OPERATION MODE, DECEMBER 1975 - APRIL 1978

Species	Life Stage(a)	Month Group	Screen Operation Mode(b)	Number of Fish	Number of Tests	Percent Survival(c) ± Standard Error	
						Initial	96-108-hr
White perch	YOY	NOV-DEC	C	6,485(2,917)(d)	45	97.4±0.2	53.4±0.9
			I-2	2,970(1,291)(d)	18	91.4±0.5	25.3±1.2
			I-4	840	15	90.0±1.0	11.9±1.2
	Y	JAN-FEB(e)	C	2,145	42	85.7±0.8	28.6±1.0
			I-2	279	4	97.8±0.9	9.1±1.7
			I-4	226	4	91.1±1.9	2.4±1.1
	Y	MAR-APR(e)	C	1,047	18	94.0±0.7	36.1±1.5
			I-2	325	4	91.4±1.5	37.7±2.8
			I-4	528	7	86.9±1.5	13.3±1.6
Striped bass	YOY	NOV-DEC	C	445(215)(d)	33	95.3±1.0	52.1±3.4
			I-2	284(139)(d)	17	93.0±1.5	23.7±3.6
			I-4	17	3	100.0±0.0	17.6±9.2
	Y	JAN-FEB(e)	C	628	43	90.0±1.2	31.9±2.0
			I-2	13	4	84.6±10.0	7.7±8.0
			I-4	14	4	92.9±6.9	0
	Y	MAR-APR(e)	C	173	16	93.6±1.8	13.6±2.7
			I-2	56	4	89.3±4.1	18.0±5.4
			I-4	175	6	89.7±2.3	3.2±1.4
Blueback herring	YOY	NOV-DEC	C	127	14	79.5±3.6	0
			I-2	6	2	66.7±19.2	0
			I-4	30	7	36.7±8.8	0
Atlantic tomcod	A	NOV-APR	C	116	10	98.3±1.2	90.1±2.8
			I-2	8	3	100.0±0.0	100.0±0.0
			I-4	5	3	100.0±0.0	60.0±21.9
Rainbow smelt	Y	FEB-APR	C	562	8	94.3±1.0	3.8±0.8
			I-2	200	7	68.0±3.3	1.5±1.0
			I-4	141	7	66.4±3.9	2.0±1.4
Hogchoker	Y	OCT	I-4	124	2	100.0±0.0	83.1±3.4

(a) Y = yearling; YOY = young of the year; A = adult.

(b) C = continuous; I-2 = intermittent 2-hour hold; I-4 = intermittent 4-hour hold.

(c) Percent survival (initial) = 100 x (no. live + no. stunned)/(no. live + no. stunned + no. dead); percent survival (96-108 hour) = 100 x (no. live + no. stunned)/(initial no. alive).

(d) Subsample (live and stunned only) taken for extended survival tests.

(e) Excludes samples collected during 1976 when no controls were conducted; data from this period are included in Appendix Tables B-1 and B-2.

TABLE 5-3 SUMMARY OF WHITE PERCH EXPERIMENTAL SURVIVAL(a) AS A FUNCTION OF SCREEN OPERATION MODE AND SEASON

		Screen Operation Mode(b)				
Month Group	Survival Observation	Continuous		2-hr		4-hr
NOV-DEC	Initial	97.0	>	91.4		90.0
	Extended(c)	51.5	>	25.3	>	11.9
JAN-FEB	Initial	94.8		97.8		91.1
	Extended	25.5	>	9.1	>	2.4
MAR-APR	Initial	94.9	>	91.4	>	86.9
	Extended	49.8	>	37.7	>	13.3

(a) Underline denotes no significant difference (X^2 test; Fleiss 1973, pp. 92-96) between groups; < denotes significantly less; > denotes significantly greater; $\alpha = 0.05$.

(b) Includes only months when continuous and intermittent 2- or 4-hour hold tests were conducted.

(c) Observation made at 96 or 108 hours.

TABLE 5-4 THE PROPORTION OF IMPINGED WHITE PERCH INITIALLY CLASSIFIED AS STUNNED

Month Group	Screen Operation Mode[a]	Initial Number Stunned	Initial Proportion Stunned
NOV-DEC	C	3,129 (1,442)[b]	0.482
	I-2	2,112 (767)	0.711
	I-4	539	0.642
JAN-FEB	C	1,518	0.698
	I-2	260	0.932
	I-4	210	0.903
MAR-APR	C	316	0.247
	I-2	116	0.357
	I-4	308	0.583

(a) C = continuous; I-2 = intermittent, 2-hour hold; I-4 = intermittent, 4-hour hold.

(b) Number in parenthesis indicates number of stunned subsampled for extended survival.

TABLE 5-5 SURVIVAL OF CONTROL FISH AS A FUNCTION OF COLLECTION TIME AT THE BOWLINE POINT PLANT, 1976-1978

Species	Life Stage[a]	Month Group	Exposure Time (min)	Number of Fish Tested	Number of Tests	Percent Survival[b] ± Standard Error: Initial	Percent Survival[b] ± Standard Error: 96-108-hr
White perch	YOY	NOV-DEC	0	127	5	100.0±0.0	79.5±3.6
			1	27	1	100.0±0.0	81.5±7.5
			10	103	4	100.0±0.0	21.4±4.0[c]
			20	130	6	93.8±2.1	48.4±4.5
			30	229	12	99.1±0.6	41.8±3.3
	Y	JAN-FEB	1	25	1	100.0±0.0	32.0±9.3[c]
			15	30	1	100.0±0.0	50.0±9.1
			30	192	7	99.5±0.5	21.5±3.0
	Y	MAR-APR	0	131	4	100.0±0.0	66.4±4.1
			1	143	4	100.0±0.0	74.1±3.7
			15	167	5	100.0±0.0	46.7±3.9
			30	288	8	100.0±0.0	37.5±2.9
	Y	MAY	1	66	1	100.0±0.0	71.2±5.6
			15	48	1	100.0±0.0	60.4±7.1
			30	80	2	100.0±0.0	53.7±5.6
Striped bass	YOY	DEC	0-30	33	6	100.0±0.0	18.2±6.7
	Y	JAN	1-30	3	2	100.0±0.0	33.3±27.2

(a) Y = yearling; YOY = young of the year.

(b) Percent surviving (Initial) = 100 x (no. live + no. stunned)/(no. live + no. stunned + no. dead); percent surviving (96-108-hour) = 100 x (no. live + no. stunned)/initial no. alive.

(c) Survival at 96-108 hours for the Jan-Feb 1-minute and Nov-Dec 10-minute exposure to the collection basket were considered to be outliers and were not included in the nonlinear regression used to estimate the collection effect for the "average fish".

TABLE 5-5 (CONT.)

Species	Life Stage[(a)]	Month Group	Exposure Time (min)	Number of Fish Tested	Number of Tests	Percent Survival[(b)] ± Standard Error Initial	Percent Survival[(b)] ± Standard Error 96-108-hr
Striped bass	Y	MAR-APR	0-30	44	17	100.0±0.0	47.7±7.5
	Y	MAY	15-30	4	3	100.0±0.0	0

5.3.1 Impinged Fish

5.3.1.1 Effect of Screenwash Frequency

Extended survival for white perch, striped bass, and Atlantic tomcod varied with wash mode in a manner similar to that observed for initial survival (Table 5-2). A significant decrease ($\alpha = 0.05$) in survival was observed for white perch as the screenhold time was increased (Table 5-3). Continuous operation resulted in highest extended survival (seasonal range was from 25.5 to 51.5 percent); survival during 4-hour hold tests (seasonal range was from 2.4 to 13.3 percent) was lowest. The same trend was observed for striped bass (Table 5-6). Extended survival for rainbow smelt was low (1.5-3.8 percent). Few blueback herring survived beyond 12 hours, and none survived to 108 hours. Hogchoker collected during 4-hour hold tests showed high 108-hour survival (83.1 percent).

Seasonal differences were observed for white perch survival (Table 5-3) under all three operational modes. Survival during winter was consistently lower (2.4-25.5 percent) than late fall (11.9-51.5 percent) and spring (13.3-49.8 percent). Striped bass displayed a similar relationship (Table 5-6), with the exception of lower survival during spring. Statistical comparison of white perch and striped bass extended survival paired by season and wash mode indicates that these congeneric species have a similar survival response to the stress of impingement, collection, and holding ($t = 3.272$, $p < 0.025$).

Survival of stunned white perch at 108 hours was lower than that observed for those initially classified as live (Table 5-7). Survival of stunned white perch collected during continuous screen wash was highest (41.2 percent) in fall and lowest (17.7 percent) in spring (Figure 5-1). At the 108-hour observation, survival of stunned fish exhibited a reduction associated with increased time between screen washes similar to that observed for live fish.

5.3.1.2 Effect of Physicochemical Variables on Extended Survival

The relationship between extended survival and water temperature and conductivity was examined to investigate seasonal variation in survival (described above). Linear regression analysis demonstrated a correlation between white perch survival at 108 hours and conductivity and water temperature during collection and holding. Air temperature was also examined (because of the potential for tissue damage from freezing during screen rotation and collection when the temperature was below 0 C), but no significant ($\alpha = 0.05$) relationship to survival was observed. When water temperature was less than 4.5 C, water temperature accounted for 81.6 percent of the variation in white perch survival (Table 5-8 and Figure 5-2), whereas conductivity accounted for 86.8 percent of the variation when water temperatures were above 4.5 C (Table 5-8 and Figure 5-3). A natural log ($\ln x$) transformation of conductivity data provided the best fit. The correlation coefficients for the two temperature groups were significant ($\alpha = 0.01$). In addition, the regression coefficient for conductivity was significant ($\alpha = 0.05$). Conductivity and water temperature exert a similar influence on striped bass survival. Although the data base was smaller, conductivity accounted for 93.9 percent of the variance above 4.5 C and water temperature accounted for 60.0 percent of the variance below 4.5 C (Table 5-8, Figures 5-2 and 5-3).

TABLE 5-6 SUMMARY OF STRIPED BASS EXPERIMENTAL SURVIVAL[a] AS A FUNCTION OF SCREEN OPERATION MODE AND SEASON

		Screen Operation Mode		
Month Group	Observation Period	Continuous	2-hr	4-hr
NOV-DEC	Initial	95.3	93.0	100.0
	Extended	52.1	23.7	17.6
JAN-FEB	Initial	90.4	84.6	92.9
	Extended	30.7	7.7	0.0
MAR-APR	Initial	93.5	89.3	89.7
	Extended	15.1	18.0	3.2

(a) These data were not tested statistically because of the low sample sizes.

TABLE 5-7 PROPORTION OF LIVE AND STUNNED WHITE PERCH SURVIVING AT LATENT-EFFECTS OBSERVATIONS AT THE BOWLINE POINT PLANT, 1975-1978

Month Group	Screen Operation Mode(a)	Stunned(b)					Live(c)				
		Number Held	Time of Observation (hr)				Number Held	Time of Observation (hr)			
			12	24-36	48-60	96-108		12	24-36	48-60	96-108
NOV-DEC	C	1,442	0.718	0.533	0.459	0.412	1,413	0.875	0.788	0.732	0.686
	I-2	767	0.881	0.464	0.318	0.197	519	0.776	0.468	0.368	0.320
	I-4	539	0.651	0.154	0.085	0.061	217	0.885	0.542	0.300	0.363
JAN-FEB	C	1,518	0.821	0.561	0.386	0.254	312	0.973	0.786	0.533	0.464
	I-2	260	0.950	0.288	0.165	0.081	13	0.923	0.538	0.538	0.308
	I-4	210	0.569	0.108	0.064	0.024	5	1.000	0.600	0.200	0.200
MAR-APR	C	316	0.642	0.441	0.358	0.177	876	0.834	0.714	0.623	0.560
	I-2	116	0.517	0.181	0.129	0.103	181	0.906	0.663	0.602	0.552
	I-4	308	0.594	0.263	0.156	0.049	151	0.848	0.503	0.384	0.305

(a) C = continuous; I-2 = intermittent, 2-hour hold; I-4 = intermittent, 4-hour hold.

(b) Proportion surviving = number alive/initial number stunned.

(c) Proportion surviving = number alive/initial number alive.

TABLE 5-8 LINEAR REGRESSION STATISTICS FOR RELATIONSHIP BETWEEN 96-108-HOUR SURVIVAL AND SELECTED PHYSICO-CHEMICAL VARIABLES AT THE BOWLINE POINT PLANT, 1975-1978

Species	Test	Temperature Group	x	n	r	r^2	Regression Coefficient	Intercept
White perch	Impinged	>4.5	Log$_e$ conductivity	13	0.931(a)	0.868	0.302(b)	-1.319
	Impinged	<4.5	Temperature	14	0.903(a)	0.816	0.180	-0.111
	Control (30 min)	>4.5	Log$_e$ conductivity	7	0.782(b)	0.611	0.232	-0.893
	Control (30 min)	<4.5	Temperature	10	0.494	0.244	0.109	0.024
	Control (Holding)	>3.0	Log$_e$ conductivity	8	0.644	0.415	0.087	0.277
	Control (Holding)	<3.0	Temperature	8	0.304	0.092	0.012	0.754
Striped bass	Impinged	>4.5	Log$_e$ conductivity	6	0.969(a)	0.939	0.171(b)	-0.796
	Impinged	<4.5	Temperature	9	0.775(b)	0.600	0.191	-0.086

(a) Significant at $\alpha = 0.01$.

(b) Significant at $\alpha = 0.05$.

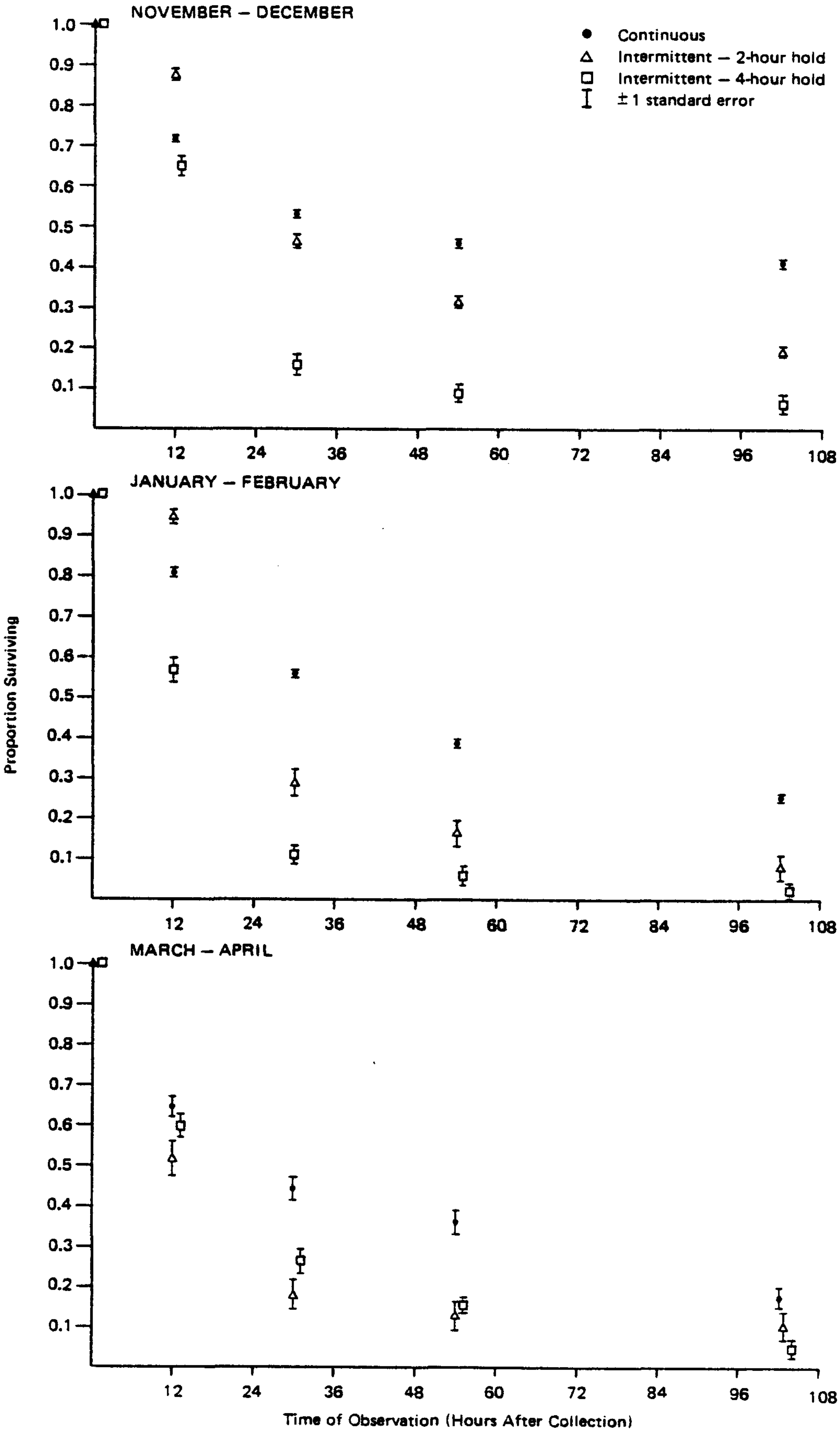


Figure 5-1. Extended survival of white perch initially classified as stunned during impingement survival studies at the Bowline Point plant, 1975-1978.

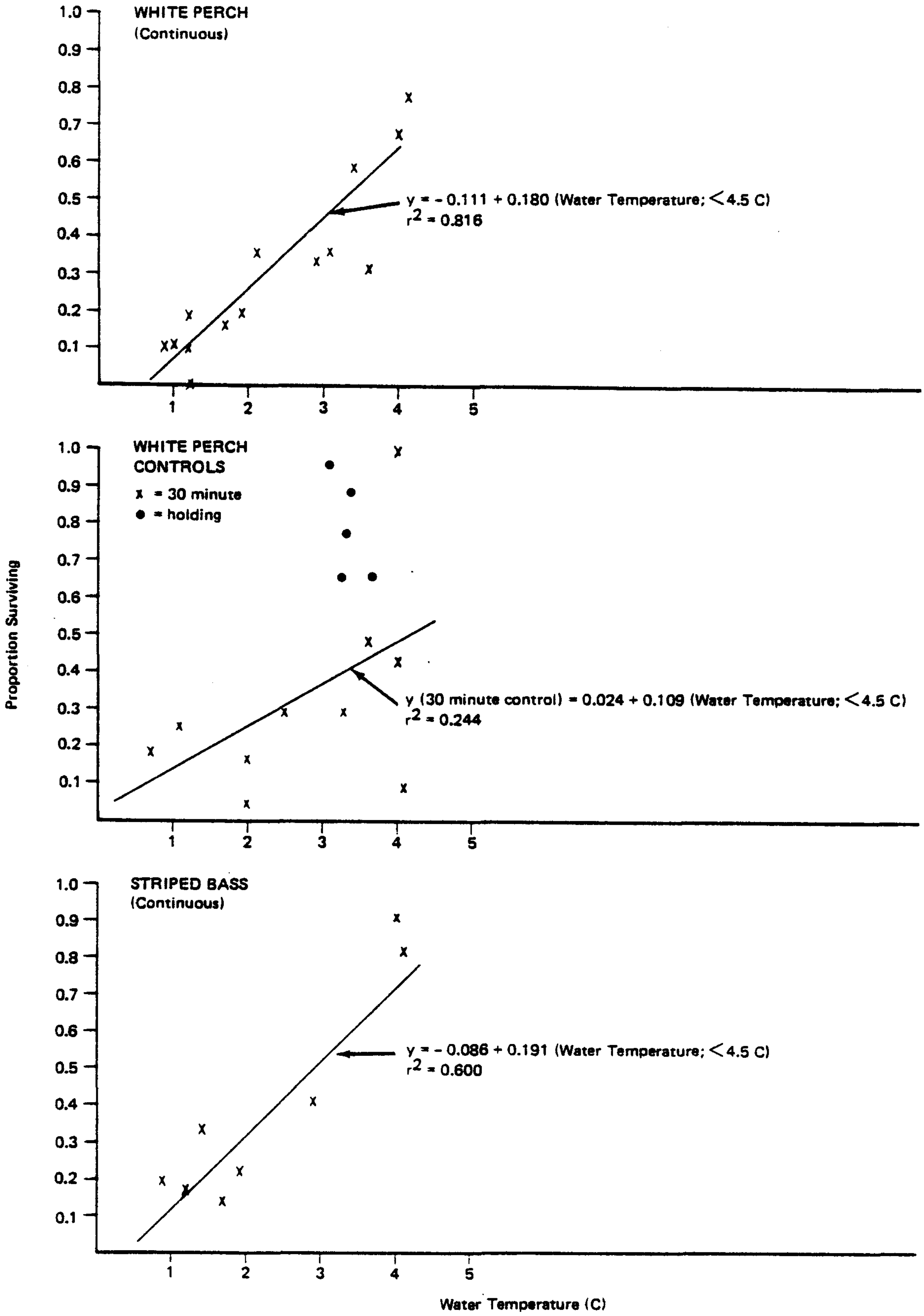


Figure 5-2. Relationship of mean water temperature to survival (at 96-108 hours) when water temperature was less than 4.5 C.

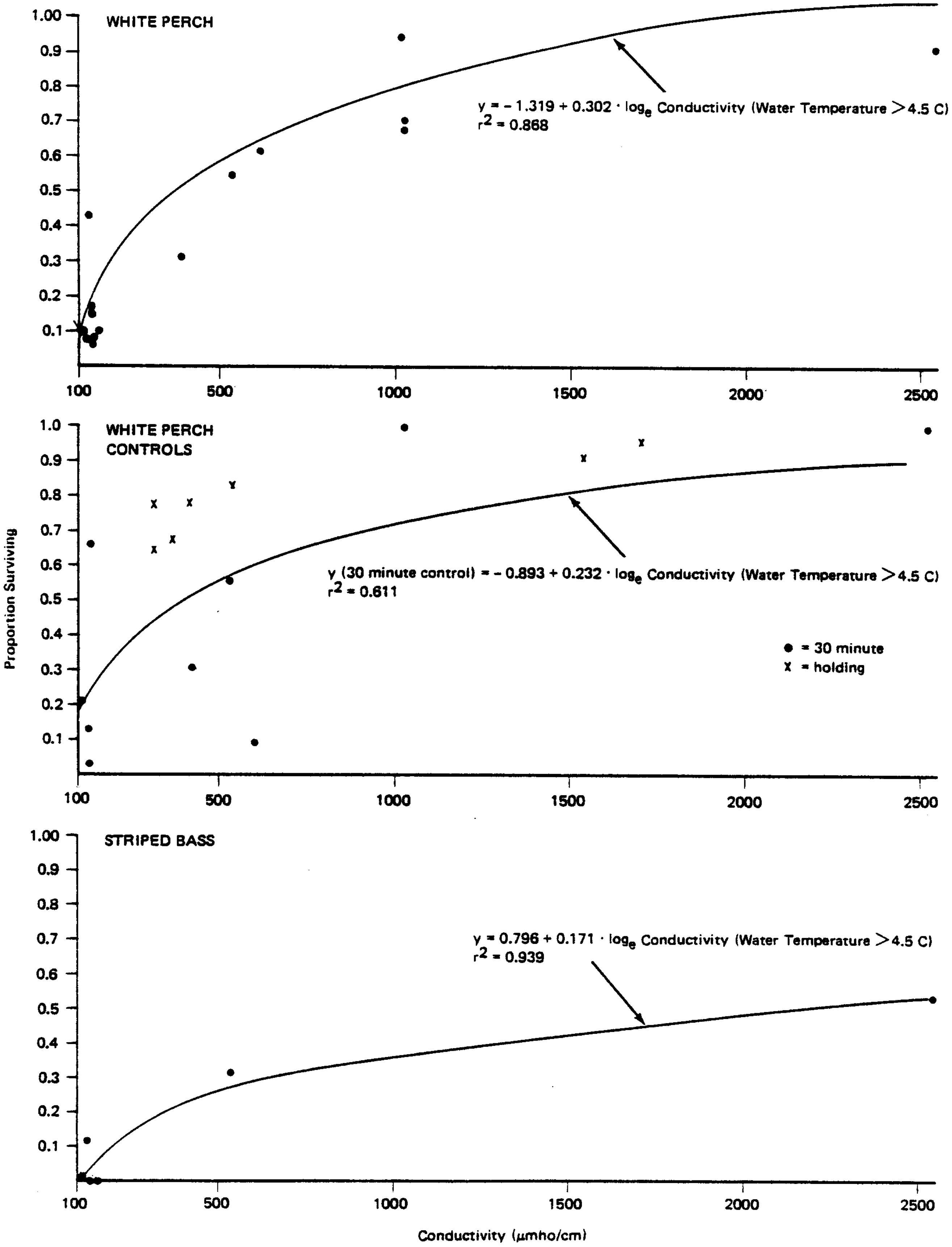


Figure 5-3. Relationship of conductivity to survival (at 96-108 hours) when water temperature was greater than 4.5 C.

5.3.2 Control Fish

Control tests were conducted to evaluate the combined effects of collection, handling, and holding on extended survival of impinged fish. Survival of white perch controls varied with exposure to the impingement collection basket for various time intervals up to 30 minutes (Table 5-5, Appendix C). Generally, a 1-minute exposure of white perch controls to the collection basket resulted in significantly ($\alpha = 0.05$) higher survival than observed at 15- and 30-minute intervals (Table 5-9, Figure 5-4). No stunning was observed in control tests.

If it is assumed that impinged fish enter the collection area at a rate which is relatively constant throughout the 30-minute wash period, the effect of the collection process is underestimated by the survival of 1-minute controls and overestimated by 30-minute controls. Therefore, the "average" survival (15 minute exposure) was predicted by non-linear regression as a best estimate of the effects of collection (Table 5-10). Handling and holding effects should be the same regardless of collection duration.

Extended control survival for white perch and striped bass declined rapidly during the first 60 hours, then leveled off at about 55 percent at 108 hours (Figure 5-5).

Water temperature and conductivity exerted an influence on white perch control survival (30-minute exposure) similar to that noted for impinged fish (Subsection 5.3.1.2). Very few control tests were conducted at temperatures below 3.5 C; however, 108-hour survival was consistently less than 30 percent (Figure 5-2). Above 4.5 C, conductivity accounted for 45.7 percent of the variance (Table 5-8, Figure 5-3). For white perch holding control survival at 108 hours, no relationship with temperature was noted; conductivity, on the other hand, accounted for 41.5 percent of this variance. No holding control data were collected at temperatures below 3.0 C.

5.4 ADJUSTMENT OF WHITE PERCH IMPINGEMENT SURVIVAL FOR HANDLING/HOLDING EFFECTS

Impingement survival for white perch was adjusted for control survival in order to correct for handling and holding effects. Adjustments and S_i calculations were made according to the formulas presented in Section 4.4.

Survival of control fish was consistently greater than impinged fish collected during all modes of screen operation in fall, winter, and spring (Tables 5-10 and C-3). The differences between control and experimental survival curves indicate that the latent effects of impingement increase with duration between screen washes and are greatest during winter. The curves for control and experimental survival diverge during the first 60 hours following impingement, but tend to level off and become parallel between 60 and 108 hours. This pattern indicates that latent mortality associated with impingement has been fully realized by the 108 hour observation. The divergence of survival curves increased with duration between screen washes and was greatest for all screen wash modes during winter. Based on these observations for latent effects, impingement survival was calculated for overall survival 108 hours after collection (Table 5-11) using 0.548 survival for control fish.

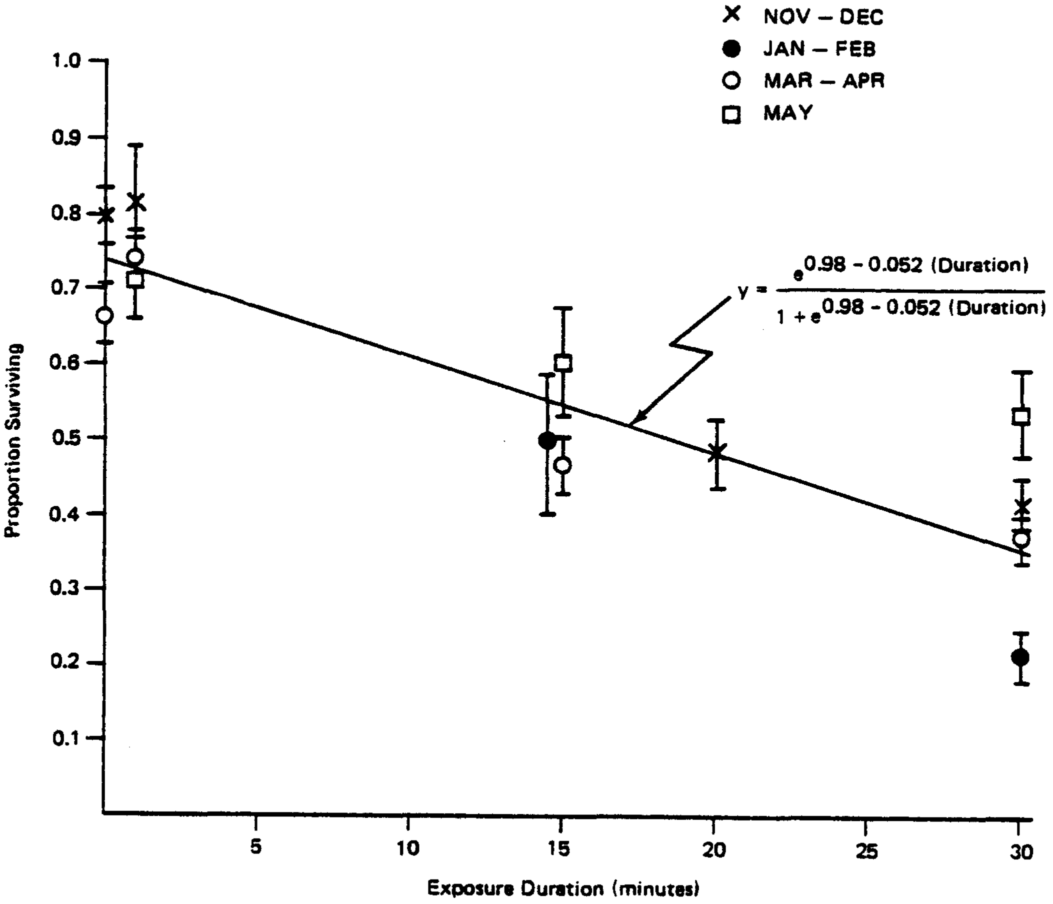


Figure 5-4. Survival of white perch controls (at 96-108 hours) in relationship to duration of exposure to the collection net at the Bowline Point plant, 1975-1978.

TABLE 5-9 SUMMARY OF EXTENDED SURVIVAL OF CONTROL WHITE PERCH AS A FUNCTION OF COLLECTION TIME

	Collection Time[a]				
Month Group	1 min		15 min		30 min
NOV-DEC	81.5	>	48.4[b]		41.8
JAN-FEB	32.0		50.0	>	21.5
MAR-APR	74.1	>	46.7		37.5
MAY	71.2	>	60.4		53.7

(a) Underline indicates no significant difference (X^2 test; Fleiss 1973; pp. 92-96), > indicates significantly greater survival; $\alpha = 0.05$.

(b) Tests were 20 minutes.

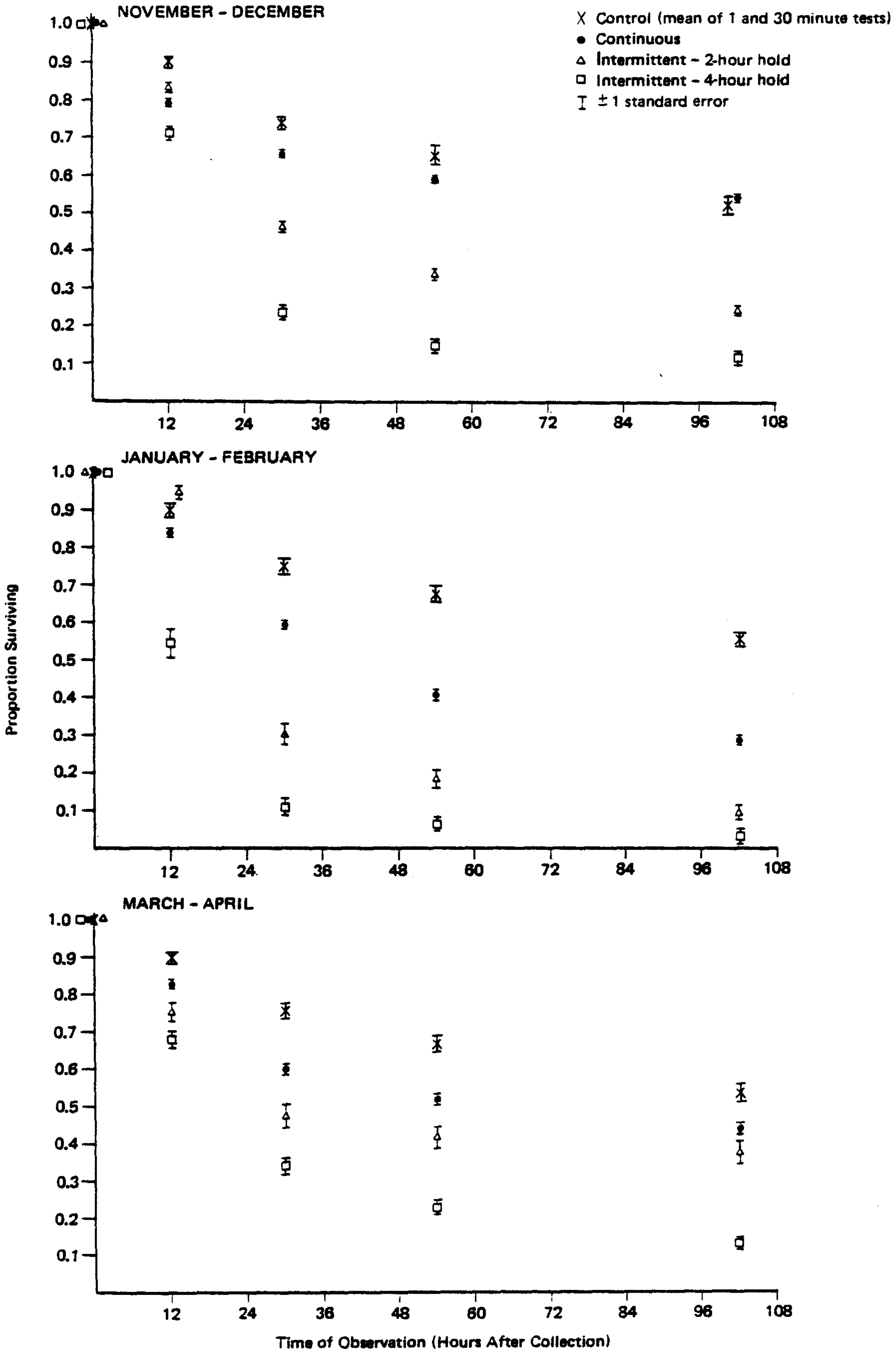
TABLE 5-10 EXTENDED SURVIVAL FOR WHITE PERCH DURING IMPINGEMENT STUDIES AT THE BOWLINE POINT PLANT BY SEASONAL MONTH GROUP, NOVEMBER 1976 - APRIL 1978

			Time of Observation (hr)							
			12		24-36		48-60		96-108	
Date	Screen Operating Mode[(a)]	Initial Number Alive[(b)]	Number	Survival Proportion[(c)]	Number	Survival Proportion	Number	Survival Proportion	Number	Survival Proportion
NOV-DEC	CNTR			0.896±0.010		0.740±0.012		0.658±0.013		0.549±0.013
	C	2,855	2,271	0.795±0.008	1,881	0.659±0.009	1,696	0.594±0.009	1,564	0.548±0.009
	I-2	1,286	1,079	0.839±0.010	599	0.466±0.014	435	0.338±0.013	317	0.246±0.012
	I-4	759	543	0.715±0.016	181	0.238±0.015	111	0.146±0.013	90	0.119±0.012
JAN-FEB	CNTR			0.896±0.010		0.740±0.012		0.658±0.013		0.549±0.013
	C	1,873	1,570	0.838±0.009	1,112	0.594±0.011	763	0.407±0.011	540	0.288±0.010
	I-2	273	259	0.949±0.013	82	0.300±0.027	50	0.183±0.023	25	0.092±0.017
	I-4	215	121	0.563±0.034	25	0.116±0.022	14	0.065±0.017	6	0.028±0.011
MAR-APR	CNTR			0.896±0.010		0.740±0.012		0.658±0.013		0.549±0.013
	C	1,192	987	0.828±0.011	715	0.600±0.014	619	0.519±0.014	527	0.442±0.014
	I-2	297	224	0.754±0.025	141	0.475±0.029	124	0.417±0.029	112	0.377±0.028
	I-4	459	311	0.678±0.022	157	0.342±0.022	106	0.231±0.019	61	0.133±0.016

(a) CNTR = predicted 15-minute control survival; C = continuous; I-2 = intermittent 2-hour hold; I-4 = intermittent 4-hour hold.

(b) Alive refers to live + stunned.

(c) Survival proportion (normalized) = (live + stunned)/initial number alive; value presented is survival ± 1 standard error.


NOVEMBER - DECEMBER

JANUARY - FEBRUARY

MARCH - APRIL

Figure 5-5. Extended survival of white perch (live and stunned) during impingement studies at the Bowline Point plant, 1975-1978.

TABLE 5-11 IMPINGEMENT SURVIVAL (S_i) FOR WHITE PERCH AT THE BOWLINE POINT PLANT

Month Group	Screen Wash Mode[(a)]	Number Collected	P_s[(b)]	S_i (%)[(c)]
NOV-DEC	C	6,485	0.534	97.4±2.6
	I-2	2,970	0.248	45.2±1.8
	I-4	840	0.076	13.9±1.7
	CNTR[(d)]		0.548	
JAN-FEB	C	2,145	0.245	44.7±2.0
	I-2	279	0.090	16.4±3.1
	I-4		0.022	4.0±1.8
	CNTR[(d)]		0.548	
MAR-APR	C	1,047	0.427	77.9±3.4
	I-2	325	0.345	63.0±5.0
	I-4	528	0.115	21.0±2.6
	CNTR[(d)]		0.548	

(a) C = continuous; I-2 = intermittent, 2-hour hold;
I-4 = intermittent, 4-hour hold;
CNTR = predicted "average" sampling effect (15 minutes).

(b) $P_s = \frac{\text{number surviving (96-108 hours)}}{\text{total number collected}}$.

(c) $S_i(\%) = 100 \frac{P_s\text{, experimental}}{P_s\text{, control}}$; ± 1 standard error.

(d) Control survival (P_3) was predicted for a 15 min exposure to the collection basket (average collection effects) using non-linear regression of survival at 108 hours and collection exposure duration.

Under continuous operation, white perch impingement survival ranged between 44.7 and 97.4 percent (Table 5-11). Survival for 2-hour hold and 4-hour hold ranged between 16.4 and 63.0 percent and 4.0 and 21.0 percent, respectively.

CHAPTER 6: DISCUSSION

6.1 INITIAL SURVIVAL

Highest initial survival of all species was observed during continuous screen rotation. Operation of the screens in the hold mode generally reduced initial survival; this result is consistent with that observed by King et al. (1977). Survival of white perch and striped bass did not show a seasonal response, which is a marked difference from the observations reported by LMS (Table 5-1). Such difference may be a result of modifications in the collection and handling techniques used in the present studies.

Control tests conducted with white perch and striped bass indicated that little initial mortality is due to collection and handling.

6.2 EXTENDED SURVIVAL AND PHYSICOCHEMICAL EFFECTS

6.2.1 White Perch and Striped Bass

A significant decrease in survival was noted for white perch and striped bass as screen hold time increased. This result is consistent with that reported by King et al. (1977). Both species exhibited seasonal changes in impingement survival, with lower extended survival during winter.

White perch control tests showed that collection and holding effects increased with the duration of exposure to the collection net and probably accounted for a considerable portion of the mortality observed among impinged fish during the extended observation period. Therefore, use of extended survival of impinged fish without consideration of sampling (collection, handling, and holding) effects, would overestimate impingement mortality. Since survival of control fish was influenced by the duration of exposure to the collection net, 1-minute tests would tend to underestimate sampling effects while 30-minute tests would overestimate these effects. Because tests of an intermediate duration were limited, the best estimation of sampling effects has been predicted by nonlinear regression analysis.

Survival (based on only those fish initially alive) of white perch was corrected for sampling effects at each latent-effects observation, and impingement survival (S_i) generally stabilized between 24 and 60 hours following collection during spring and fall. This indicates that the full direct effect of impingement is realized within 24-36 hours of collection during these time periods. However, the latent effect of impingement during winter continued to be observed up to 60 hours. Because 108-hour survival (based on all fish collected) reflects both the initial and latent effects of the impingement and sampling process, this value was used to derive an estimate of impingement survival which accounts for the maximum effect of impingement.

When survival of impinged white perch at 108 hours was adjusted for sampling effects, seasonal and screen-mode effects were observed. Whereas survival under continuous operation was 78-97 percent in fall and spring, survival in winter declined to 45 percent. The hold modes exhibited a similar pattern; however, operation of the screens in the hold mode resulted in a more stressful condition, with survival between 4 and 63 percent. The control data for striped bass was too limited to make corrections similar to those made for white perch. However, similarities between striped bass and white perch initial and extended survival would indicate that impingement survival (S_i) of these two closely related species is also similar.

Fish impinged during different seasons and wash modes exhibited various degrees of stunning. Greater stunning was noted with increased hold times between washes and in the winter time period. Control fish did not exhibit any stunning when subjected to the collection basket and handling; therefore, stunning probably is a result of the impingement process. Generally, a lower proportion of those fish initially classified as stunned survived through 108 hours than of those initially classified as live.

Higher conductivity at temperatures greater than 4.5 C was associated with higher extended survival of impinged white perch and striped bass, 30-minute white perch controls, and white perch holding-facility controls. This relationship was suppressed at water temperatures below 4.5 C, which is reflected by the lower observed survival of impinged white perch and striped bass during the winter months.

The improvement in extended survival observed with increased conductivity is similar to the prophylactic effect of salt reported by Collins and Hulsey (1963), Miles et al. (1974) and Hattingh et al. (1975). Such enhanced survival in the holding facility may be related to the alleviation of osmoregulatory dysfunction or hyperglycemia (Wedemeyer 1972; Miles et al. 1974; and Hattingh and Van Pletzer 1974) associated with stress.

White perch and striped bass 108-hour survival was observed to be related to water temperatures below 4.5 C. As temperature increased, survival in the holding facilities increased. Since similar results were noted for white perch 30-minute controls, but not for holding controls, this effect may be related to an interaction between stress of impingement, collection, and low temperatures. Increased mortality due to the addition of stress at low temperatures has been noted in other studies (Stanley and Colby 1971; Colby 1973; Umminger and Gist 1973; and Otto et al. 1976). Such mortality may be attributed to increased osmoregulatory dysfunction. Also, temporary freezing of fish out of water during screen rotation before they reach the height of the wash nozzles may be a source of additional stress. These factors may also contribute to the higher degree of stunning observed for impinged fish during the winter months and the depressed S_i values for winter.

Since no holding control data were available at temperatures below 3.0 C, the effect of very low holding temperatures on survival has not been documented. Consequently, it has not been possible to determine whether the low survival observed below 3.0 C (Jan-Feb) is a result of impingement, collection, or holding.

6.2.2 Other Species

Based upon the results of this study, initial and extended impingement survival (S_i) of hogchoker and Atlantic tomcod would be expected to be high during both continuous and intermittent screen operation. King et al. 1977 also concluded that screen operation mode and screenwash pressure had little apparent effect on Atlantic tomcod survival.

While initial survival of rainbow smelt and blueback herring was high (79.5 to 94.3 percent) during continuous screen operation, few rainbow smelt and no blueback herring survived to 108 hours. Since no control groups were available to determine potential effects of handling and holding, the latent effect of impingement on these species cannot be estimated. Texas Instruments (1978) reported similar results for both rainbow smelt and blueback herring impinged under continuous operation of a fine-mesh screen.

6.3 CONCLUSIONS

These studies were conducted to determine the mode of operation that would maximize fish survival; the factor influencing survival; and the impingement survival factors which should be used for impact assessment at the Bowline Point Generating Station. The results of these studies have demonstrated the following:

1. Impingement survival increases with decreasing time between screen washes. Continuous operation resulted in the highest survival for all species observed.

2. Seasonal differences were observed, with lower survival and greater stunning observed for white perch in winter.

3. The presence of higher salinity water enhanced the ability to hold white perch and striped bass through the latent effects observation period. The presence of the salt front in the vicinity of Bowline Point may enhance survival upon return to the waterbody.

4. Little effect of impingement on survival percentages of hogchoker and Atlantic tomcod was noted:

	Mode		
		Intermittent	
Species	Continuous	(2-Hr Hold)	(4-Hr Hold)
Atlantic tomcod	90	100	60
Hogchoker	-	-	83

5. Initial survival of blueback herring and rainbow smelt collected under continuous operation was high. No control data were collected to determine handling or holding effects. No blueback herring and few smelt survived through the 108-hour observation.

6. Impingement survival (corrected for sampling effects) for white perch at the Bowline Point Generating Station in normal operating modes was

	Mode	
Season	Continuous	Intermittent (4-Hr Hold)
Fall	97.4±2.6	13.9±1.7
Winter	44.7±2.0	4.0±1.8
Spring	77.9±3.4	21.0±2.6

It is expected that striped bass impingement survival would be similar to white perch based on the similarity of extended survival observed for these two closely related species.

REFERENCES

Colby, P. J. 1973. Response of the alewives, Alosa pseudoharengus, to environmental change, in Responses of Fish to Environmental Changes (W. Chavin, ed.), pp. 163-198. C. C. Thomas, Springfield, Ill.

Collins, J. L., and A. H. Hulsey. 1963. Hauling mortality of threadfin shad reduced with M.S. 222 and salt. Prog. Fish-Cult. 25:105-106.

DeAngelis, D. L., S. W. Christensen, and A. G. Clark. 1977. Responses of a fish population to young-of-the-year mortality. J. Fish. Res. Board Can. 34(11): 2124-2132.

Dixon, W. J., and M. B. Brown. 1977. BMDP-77. Biomedical Computer Programs, P-Series. University of California Press.

Ecological Analysts, Inc. (EA). 1977. Bowline Point Generating Station Entrainment and Impingement Studies. 1976 Annual Report. Prepared for Orange and Rockland Utilities, Inc.

Fleiss, J. L. 1973. Statistical Methods for Rates and Proportions, pp. 92-96. Wiley, N.Y.

Grimes, C. B. 1975. Entrapment of fishes on intake water screens at a steam electric generating station. Ches. Sci. 16(3):172-177.

Hanson, C. H., J. R. White, and H. W. Li. 1977. Entrapment and impingement of fishes by power plant cooling water intakes: an overview. Marine Fish. Rev. 39(10):7-17.

Hattingh, J., and A. J. J. Van Pletzen. 1974. The influence of capture and transportation on some blood parameters of fresh water fish. Comp. Biochem. Physiol. 49A:607-609.

Hattingh, J., F. L. Fourie, and J. H. J. Van Vuren. 1975. The transport of freshwater fish. J. Fish. Biol. 7:447-449.

King, L. R., J. B. Hutchison, Jr., and T. G. Huggins. 1978. Impingement survival studies on white perch, striped bass, and Atlantic tomcod at three Hudson River power plants, in Fourth National Workshop on Entrainment and Impingement (L. D. Jensen, ed.). EA Communications, Melville, N.Y.

Lawler, Matusky and Skelly Engineers (LMS). 1974. 1973 Hudson River Aquatic Ecology Studies--Bowline Point and Lovett Generating Stations. Volume V. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky and Skelly Engineers (LMS). 1975. 1974 Hudson River Aquatic Ecology Studies--Bowline Point and Lovett Generating Stations. Volume II. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky and Skelly Engineers (LMS). 1976. 1975 Hudson River Aquatic Ecology Studies--Bowline Point and Lovett Generating Stations. Volume I. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky and Skelly Engineers (LMS). 1977. 1976 Hudson River Aquatic Ecology Studies at Bowline Point Generating Station. Volume I. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky and Skelly Engineers (LMS). 1978. 1977 Hudson River Aquatic Ecology Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities, Inc.

Mathur, D., P. G. Heisey, and N. C. Magnusson. 1977. Impingement of fishes at Peach Bottom Atomic Power Station, Pennsylvania. Trans. Amer. Fish. Soc. 106(3):258-267.

Miles, H. M., S. M. Loehner, D. T. Michaud, and S. L. Salivar. 1974. Physiological responses of hatchery reared muskellunge (Esox masquinongy) to handling. Trans. Amer. Fish. Soc. 103:336-342.

Orange and Rockland Utilities, Inc. (ORU). 1977. Bowline Point Generating Station: Near-Field Effects of Once-Through Cooling Systems Operation on Hudson River Biota.

Orange and Rockland Utilities, Inc. (ORU). 1978. Bowline Point Generating Station: 316(a) Demonstration.

Otto, R. G., M. A. Kitchel, and J. O'Hara Rice. 1976. Lethal and preferred temperatures of the alewife (Alosa pseudoharengus) in Lake Michigan. Trans. Amer. Fish. Soc. 105(1):96-106.

Stanley, J. G., and P. J. Colby. 1971. Effects of temperature on electrolyte balance and osmoregulation in alewife (Alosa pseudoharengus) in fresh and sea water. Trans. Amer. Fish. Soc. 100:624-638.

Texas Instruments, Inc. 1978. Initial and Extended Survival of Fish Collected from a Fine Mesh Continuously Operating Traveling Screen at the Indian Point Generating Station for the Period 15 June - 22 December 1977. Prepared for Consolidated Edison Company of New York, Inc.

Umminger, B. L., and D. H. Gist. 1973. Effects of thermal acclimation on physiological responses to handling stress, cortisol and aldosterone injections in the goldfish, Carassius auratus. Comp. Biochem. Physiol. 44A: 967-977.

Umminger, B. L. 1971. Osmoregulatory role of serum glucose in freshwater-adapted killifish (Fundulus heteroclitus) at temperatures near freezing. Comp. Biochem. Physiol. 38A:141-145.

Van Winkle, W. (ed.). 1977. Assessing the effects of power-plant induced mortality on fish populations. Pergamon, New York. 380 pp.

Van Winkle, W., D. L. DeAngelis, and S. R. Blum. 1978. A density-dependent function for fishing mortality rate and a method for determining elements of a Leslie matrix with density dependent parameters. Trans. Am. Fish. Soc. 107(3):395-401.

Wedemeyer, G. 1972. Some physiological consequences of handling stress in the juvenile coho salmon (*Onchorhynchus kitsutch*) and steelhead trout (*Salmo gairdneri*). J. Fish. Res. Board. Can. 29:1780-1783.

APPENDIX A

MODIFICATIONS TO THE SAMPLING PROCEDURE

APPENDIX A: MODIFICATIONS TO THE SAMPLING PROCEDURE

Occasional modifications to the sampling design, equipment, or procedures were made between December 1975 and May 1978 in conjunction with changes in the objectives of the study and in an attempt to reduce the effects of handling, collection, and holding on fish survival. These modifications are described below and summarized in Table A-1.

A.1 DECEMBER 1975 - APRIL 1976

Surveys were conducted once per month, with the exception of April, when two surveys were conducted. Sample collections were made at the impingement collection pit under continuous screenwash mode, with the screenwash system adjusted to approximately 2.1 kg/cm^2 (30 psi); the dual pressure system had not been completed.

The holding tanks were set up in the laboratory until air temperature was consistently above 0 C; in April, the facilities were moved to the intake catwalk. Flow-through containers (60 x 45 x 30 cm) were used for holding the test fish.

The collection nets were emptied and fish were sorted every 30 minutes. These collections were then composited for a 3-hour sample. Impinged fish from Unit 1 and Unit 2 were mixed in the collection net and processed as a single sample.

Control fish were collected by seine, electroshocker, and trap nets. These fish were distinguished from impinged fish during test runs by caudal finclips and were subjected to the collection gear for 30 minutes.

Extended survival was observed for all species collected at 6-, 12-, 24-, 36-, 48-, and 96-hour intervals. Total length (to the nearest millimeter) was recorded for each fish at the time that death was observed.

A.2 NOVEMBER-DECEMBER 1976

Impingement survival studies were conducted 2 nights per week for 6 weeks in November-December 1976. Screenwash operational modes tested were: continuous (November-December), intermittent (4-hour hold) with a 20-minute screenwash (November), and intermittent (2-hour hold) with a 10-minute screenwash (December). The high-pressure screenwash system was set at 4.2 kg/cm^2 (60 psi) (resulting in a 40-60 psi range), and the low-pressure screenwash system was adjusted to 1.4 kg/cm^2 (20 psi) (resulting in a 10-39 psi range). The sampling regime, with associated screenwash operating modes is presented below:

Day	Sampling Period	Operating Mode	Pressure
1	1700-2300	Continuous	High
1	2300-0500	Continuous	High/low
2	1700-2300	Intermittent	High
2	2300-0500	Intermittent	High/low

The sequence of high and high/low pressure operation was alternated during each subsequent sampling week.

TABLE A-1 SAMPLING GEAR AND METHODS USED TO COLLECT FISH FOR IMPINGEMENT VIABILITY AT THE BOWLINE POINT PLANT, 1975-1978

Year	Season	Collection Site	Units Sampled For Survival	Operating Mode	Screenwash Pressures
1975-76	DEC 75-APR 76	Impingement collection pit	Units 1 and 2 combined	Continuous	High pressure system: 30 psi
1976	NOV-DEC	Impingement collection pit; sluiceway discharge pipe	NOV-Units 1 and 2 combined DEC-Unit 1 separate from Unit 2: viability on all Unit 1 samples and Unit 2 continuous low pressure samples	NOV-Continuous; intermittent 4-hr (20-min screenwash); DEC-Continuous; intermittent 2-hr (10-min screenwash)	Low pressure system: 10-39 psi and/or high pressure system: 40-60 psi
1977	JAN-APR	Impingement collection pit; sluiceway discharge pipe	Unit 1 separate from Unit 2: viability on all Unit 1 samples and Unit 2 continuous low pressure samples	Continuous; intermittent 4-hr (20-min screenwash)	Low pressure system: 10-39 psi and/or high pressure system: 40-60 psi
1977	OCT-DEC	Impingement collection pit	Unit 1 collected separately from Unit 2 but combined for viability	OCT-Intermittent 4-hr DEC-Continuous; intermittent 2-hr; intermittent 4-hr (20-min screenwash)	Low pressure system: 10-39 psi and high pressure system: 40-60 psi
1978	JAN-MAY	Impingement collection pit	Unit 1 collected separately from Unit 2 but combined for viability	Continuous; intermittent 2-hr; intermittent 4-hr (20-min screenwash)	Low pressure system: 10-39 psi and high pressure system: 40-60 psi

TABLE A-1 (EXTENDED)

Year	Season	Physico-Chemical Data Recording	Control Fish Collection Methods	Control Characteristics	Control Fish Identification	Holding Facilities
1975-76	DEC 75-APR 76	Martek or YSI once per composite	Seine, electroshock, trap net	30-min runs: adult white perch and gizzard shad	Finclip	Flow-through containers
1976	NOV-DEC	Martek or YSI with backup units same frequency as operational data	Seine, electroshock, trawl, impingement	10-, 20-, 30-min young-of-the-year white perch (all stations)	Finclip and isolation with sluiceway barrier net	Flow-through containers 2x3 ft diameter cylindrical tanks (for clupeid)
1977	JAN-APR	Martek or YSI with backup units same frequency as operational data	Impingement, trawl	20- and 30-min runs (all stations)	Isolation with sluiceway barrier net	Flow-through containers, 2x3 ft diameter cylinrical tanks (for clupeids)
1977	OCT-DEC	Martek or YSI with backup units same frequency as operational data	Trawl	1-, 10-, 15-, 20-, and 30-min runs holding controls	Isolation with sluiceway barrier net	Flow-through con-containers, 2x3 ft diameter cylindrical tanks (for excess--all species)
1978	JAN-MAY	Martek or YSI with backup units same frequency as operational data	Trawl	1-, 15-, 30-min runs holding controls	Isolation with sluiceway barrier net	2x3 ft diameter cylindrical tanks (for all species)

TABLE A-1 (EXTENDED)

Year	Season	Species Held for Extended Survival	Continuous Mode Collection Intervals	Continuous Mode Composite Durations	Recorded Sample Time	Operational Data Monitoring Frequency
1975-76	DEC 75-APR 76	All species collected	30 minutes	3 hours	Termination of the composite	Hourly
1976	NOV-DEC	white perch, striped bass, Atlantic tomcod, blueback herring, alewife	30 minutes	2 hours	Continuous: midtime Intermittent: termination Discharge Pipe: start time	2-hr intervals coinciding with recorded sample time for continuous and 2-hr intermittent
1977	JAN-APR	white perch striped bass Atlantic tomcod blueback herring alewife	30 minutes	2 hours	Continuous: midtime Intermittent: termination Discharge Pipe: start time	2-hr intervals coinciding with recorded sample time for continuous and 2-hr intermittent
1977	OCT-DEC	OCT--blue crabs and hogchokers DEC--white perch, striped bass, Atlantic tomcod, blueback herring, alewife	30 minutes	2 hours	Continuous: midtime Intermittent: termination	2-hr intervals coinciding with recorded sample time for continuous and 2-hr intermittent
1978	JAN-MAY	All species collected	30 minutes	6 hours	Continuous: midtime Intermittent: termination	At the designated sample time

TABLE A-1 (EXTENDED)

Year	Season	Latent-Effects Observations	Fish Length	Barrier Net Deployment	Special Observations
1975-76	DEC 75-APR 76	6, 12, 24, 36, 48, and 96 hr	Measured to nearest mm	None	None
1976	NOV-DEC	1 NOV--14 DEC 12, 24, 48, 96 hr 6 DEC--15 DEC 12, 36, 60, 108 hr	Size classifications: young of year yearling adult	1.27 cm across Unit 2 0.95 cm across Unit 1	December: subsamples
1977	JAN-APR	12, 36, 60, and 108 hr	Size classifications: young of year yearling adult	1.27 cm across Unit 2 0.95 cm across Unit 1	Special Control Study fed and non-fed replicates (with 1, 15, and 30 min and holding controls)
1977	OCT-DEC	12, 36, 60, and 108 hr	Size classifications: young of year yearling adult	0.95 cm across Unit 1 and Unit 2	All experimental groups fed; fed and non-fed control replicates when possible
1978	JAN-MAY	12, 36, 60, and 108 hr, thereafter every 24 hr for 2 wk (continuous mode)	Size classification: young of year yearling adult	0.95 across Unit 1 and Unit 2	All experimental groups fed; fed and non-fed control replicates, observation of parasitism, fungus, bacteria, and stomach contents

White perch, striped bass, and Atlantic tomcod were held for extended survival observations in the flow-through containers. Alewife and blueback herring were held in the cylindrical tanks.

Control fish were collected primarily by short-duration trawl, although seine, electroshocker, and intake screens were also used. Fish collected by each method were held separately for 48-72 hours before use in tests. Control fish were finclipped, and sluiceway barrier nets were installed to separate control fish from impinged fish. Control fish were held in the collection net for 10-, 20-, and 30-minute intervals.

Impingement survival samples were collected every 30 minutes and combined as 2-hour composites for the continuous wash mode. Collections made in November 1976 combined impinged fish from Unit 1 and Unit 2. In December 1976, the intake and steel mesh baskets were modified to separate impinged fish collected at each unit. Latent effects were observed at Unit 1 under all three operational modes and at Unit 2 for the continuous low-pressure modes only.

During the peak impingement period in December, it was necessary to subsample impingement collections, because of the limited space in the holding facilities. A maximum of 40 live and 40 stunned fish were selected at random to be observed for extended survival. The remaining fish were counted and identified, and their initial condition was recorded.

Extended survival was monitored at 12, 24, 48, and 96 hours after collection from 1 November to 4 December, and at intervals of 12, 24-36, 48-60, and 96-108 hours from 6 to 15 December. Test fish were classified by size groups: young of the year, yearling, or adult (see Subsection 4.1).

A.3 JANUARY-DECEMBER 1977

Collection and handling procedures for 1977 remained essentially unchanged from those used in November and December 1976.

From 27 January to 8 April 1977, eight impingement survival surveys were conducted and extended survival was monitored at 12-, 36-, 60-, and 108-hour intervals.

A separate control study was conducted on 31 March to evaluate collection and handling stresses for various exposure times. Control fish were subjected to the collection net in the impingement collection pit for 1-minute, 15-minutes, or 30-minutes. Test runs were replicated; fish from one set of replicates were fed freeze-dried tubifex worms and fish from the other set of replicates were not fed throughout the extended survival observations. The continuous high/low pressure screenwash was run during the control tests. Collections, sorting, and extended survival observations were conducted in the same manner as for impingement samples.

Impingement survival studies were conducted 3 days per week for 2 weeks in December 1977. A different screenwash operational mode was tested on each day of a week's sampling effort. The modes tested were: continuous, intermittent 2-hour hold with a 20-minute screenwash, and intermittent 4-hour hold with a 20-minute screenwash. The screenwash pressure system was redesigned and operated with the high-pressure system adjusted to approximately 4.2 kg/cm^2 (60 psi) and the low-pressure system set at approximately 2.1 (30 psi).

Fish impinged at Unit 1 were collected separately from those impinged at Unit 2 in order to provide separate abundance counts for each unit; however, extended survival observations were made for the combined samples. Sluiceway barrier nets were used to separate control fish from impinged fish during collection. Control test durations included 1-, 15-, and 30-minute exposures and holding controls. When sufficient control fish were available, replicate experiments were conducted and fish from one set were fed. Control fish and all impinged test fish were fed Tetra brine-shrimp mix, freeze-dried Euphasia pacifica, or freeze-dried tubifex worms. Fish were held in flow-through holding containers. When these containers were filled, excess test fish were held in the cylindrical tanks to avoid subsampling. Extended survival observations were made at 12, 36, 60, and 108 hours following collections.

A.4 JANUARY-MAY 1978

Impingement survival tests were conducted twice per month during January and February 1978 and four times in April. A special control fish study was conducted in May. Collection and handling procedures were essentially unchanged from those used in December 1977. The high/low pressure system was used during continuous, intermittent 4-hour, and intermittent 2-hour screenwash operational modes. Cylindrical holding tanks were used for all species. The sampling regime, with associated screenwash operating modes was as follows:

Day	Sampling Period	Operating Mode
1	1700-0100	Continuous
2	1300-1700	Intermittent 4-hr
2	1700-2100	Intermittent 4-hr
2	2100-2300	Intermittent 2-hr
2	2300-0100	Intermittent 2-hr

Collections were made every 30 minutes during the continuous screenwash and composited for the 6-hour sampling period. Collections from Unit 1 and Unit 2 were combined for survival observations. Control fish were exposed to the collection net for 1-, 15-, and 30-minute intervals in addition to holding controls. All fish from test and control samples were fed, except when replicate control samples were obtained and only one set of controls was fed. Extended survival was monitored at 12-, 36-, 60-, and 108-hour intervals for all species collected. At the conclusion of the 108-hour observation, if more than 25 fish from the continuous screenwash tests remained alive, observations were continued every 24 hours until 336 hours.

All test fish were examined for external damage, and the presence of fungus and/or bacteria. A subsample of the dead fish removed at each observation was examined for internal parasites and presence of food in the stomachs.

APPENDIX B

INITIAL AND 96-108-HOUR SURVIVAL DATA BY MONTH FOR THE BOWLINE POINT PLANT IMPINGEMENT STUDIES, 1975-1978

TABLE B-1 WHITE PERCH SCREEN SURVIVAL AT THE BOWLINE POINT PLANT, 1975-1978

Date	Year Class[a]	Screen Operating Condition[b]	Number Collected	Subsample Size	Initial Number Alive	Proportion Surviving[c]	
						Initial	96-108-hr
DEC 1975	YOY	C	125		124	0.992±0.008	0.952±0.019
JAN 1976	Y	C	7		4	0.571±0.187	0.429±0.247
FEB 1976	Y	C	31		30	0.968±0.032	0.355±0.087
MAR 1976	Y	C	55		34	0.618±0.066	0.073±0.045
APR 1976	Y	C	178		175	0.983±0.010	0.427±0.037
NOV 1976	YOY	C	570		523	0.917±0.012	0.526±0.022
	YOY	I-4	254		181	0.713±0.028	0.033±0.013
DEC 1976	YOY	C	5,312	1,744[d]	5,184	0.976±0.002	0.552±0.012
	YOY	I-2	2,383	704[d]	2,133	0.895±0.006	0.293±0.017
JAN 1977	Y	C	234		94	0.402±0.032	0.107±0.032
FEB 1977	Y	C	1,622		1,471	0.907±0.007	0.265±0.012
MAR 1977	Y	C	73		55	0.753±0.050	0.096±0.040
	Y	I-4	193		178	0.922±0.019	0.072±0.019
APR 1977	Y	C	122		105	0.861±0.031	0.082±0.027
DEC 1977	YOY	C	478		463	0.969±0.008	0.379±0.023
	YOY	I-2	587		582	0.991±0.004	0.189±0.016
	YOY	I-4	586		575	0.981±0.006	0.096±0.012
JAN 1978	Y	C	173		171	0.988±0.008	0.335±0.036
	Y	I-2	234		231	0.987±0.007	0.085±0.018
	Y	I-4	199		182	0.915±0.020	0.025±0.012
FEB 1978	Y	C	116		103	0.888±0.029	0.103±0.030
	Y	I-2	45		42	0.933±0.037	0.111±0.048
	Y	I-4	27		24	0.889±0.060	0.042±0.041

(a) Y = yearling; YOY = young of the year.

(b) C = continuous; I-2 = intermittent 2-hour hold; I-4 = intermittent 4-hour hold.

(c) Proportion surviving = (live + stunned)/(live + stunned + dead); ± 1 standard error.

(d) Subsample included live and stunned only.

TABLE B-1 (CONT.)

Date	Year Class[a]	Screen Operating Condition[b]	Number Collected	Subsample Size	Initial Number Alive	Proportion Surviving[c] Initial	96-108-hr
APR 1978	Y	C	852		823	0.966±0.006	0.505±0.022
	Y	I-2	325		297	0.914±0.016	0.345±0.028
	Y	I-4	335		281	0.839±0.020	0.140±0.021

(a) Y = yearling; YOY = young of the year.

(b) C = continuous; I-2 = intermittent 2-hour hold; I-4 = intermittent 4-hour hold.

(c) Proportion surviving = (live + stunned)/(live + stunned + dead); ± 1 standard error.

(d) Subsample included live and stunned only.

TABLE B-2 STRIPED BASS SCREEN SURVIVAL AT THE BOWLINE POINT PLANT, 1976-1978

Date	Screenwash Operating Condition(a)	Number Collected	Subsample No.(b)	Initial Number Alive	Proportion Surviving(c)	
					Initial	96-108 Hour
JAN 1976	C	1		1	1.000±0.0	0
FEB 1976	C	30		30	1.000±0.0	0.100±0.055
MAR 1976	C	3		3	0.667±0.272	0
APR 1976	C	8		8	1.000±0.0	0.250±0.153
NOV 1976	C	5		3	0.600±0.219	0.400±0.283
DEC 1976	C	438	205	419	0.957±0.010	0.542±0.024
	I-2	269	124	249	0.926±0.016	0.250±0.027
JAN 1977	C	52		31	0.596±0.068	0.192±0.071
FEB 1977	C	543		505	0.930±0.011	0.306±0.020
MAR 1977	C	22		19	0.864±0.073	0
	I-4	109		106	0.972±0.016	0.018±0.013
APR 1977	C	13		12	0.923±0.074	0.154±0.104
DEC 1977	C	2		2	1.000±0.0	0.500±0.354
	I-2	15		15	1.000±0.0	0.133±0.088
	I-4	17		17	1.000±0.0	0.176±0.092
JAN 1978	C	16		14	0.875±0.083	0.250±0.116
	I-2	1		1	1.000±0.0	0
	I-4	5		5	1.000±0.0	0
FEB 1978	C	17		15	0.882±0.078	0
	I-2	12		10	0.833±0.108	0.083±0.087
	I-4	9		8	0.889±0.105	0
APR 1978	C	138		130	0.942±0.020	0.159±0.032
	I-2	56		50	0.893±0.041	0.161±0.052
	I-4	66		51	0.773±0.052	0.045±0.029

(a) C = continuous; I-2 = intermittent 2-hour hold; I-4 = intermittent 4-hour hold.

(b) Subsample includes live and stunned only.

(c) Proportion surviving = (live + stunned)/(live + stunned + dead); ± 1 standard error.

TABLE B-3 SURVIVAL OF OTHER IMPINGED SPECIES COLLECTED OCCASIONALLY AT THE BOWLINE POINT PLANT, 1975-1978

Species	Screen Operating Condition[a]	Screen Initial Number Collected	Screen Initial Proportion Surviving[b]	Screen 96-108 Hour Proportion Surviving[c]
Alewife	Continuous	41	0.756	0
	Intermittent	3	0.333	0
	Combined	44	0.727	0
Three-spine stickleback	Continuous	11	0.909	0.900
	Intermittent	7	0.857	0.833
	Combined	18	0.889	0.875
Tesselated darter	Continuous	12	1.000	1.000
	Intermittent	6	0.833	1.000
	Combined	18	0.944	1.000
Banded killifish	Combined	2	1.000	1.000
Mummichog	Combined	10	1.000	0.900
Goldfish	Combined	3	1.000	0
Spottail shiner	Continuous	3	0.667	1.000
White catfish	Combined	3	1.000	0.667
Largemouth bass	Intermittent	1	1.000	0
Red breast	Continuous	1	1.000	0
Bluegill	Combined	5	1.000	0.400
Gizzard shad	Combined	8	0.625	0
American eel	Combined	3	0.333	0
Yellow perch	Continuous	1	1.000	1.000
Northern pipefish	Continuous	1	1.000	1.000
Blue crab	Intermittent	140	0.979	0.956

(a) Intermittent mode combines 2-hour and 4-hour hold modes.

(b) Proportion surviving = (no. live + no. stunned)/(no. live + no. stunned + no. dead).

(c) Proportion surviving = (no. live + no. stunned)/initial no. alive.

APPENDIX C

EXTENDED SURVIVAL DATA FOR THE BOWLINE POINT PLANT IMPINGEMENT STUDIES, 1975-1978

TABLE C-1 EXTENDED SURVIVAL OF WHITE PERCH DURING IMPINGEMENT STUDIES AT THE BOWLINE POINT PLANT BY MONTH, 1975-1978

Date	Screen[a] Operating Mode	Initial Number Alive	Time of Observation							
			12 Hour		24-36 Hour		48-60 Hour		96-108 Hour	
			No.	Proportion Surviving[b]	No.	Proportion Surviving	No.	Proportion Surviving	No.	Proportion Surviving
DEC 1975	C	124	124	1.000	122	0.984	121	0.976	119	0.960
JAN 1976	C	4	4	1.000	4	1.000	3	0.750	3	0.750
FEB 1976	C	30	26	0.867	21	0.700	19	0.633	11	0.367
MAR 1976	C	34	34	1.000	6	0.176	6	0.176	4	0.118
APR 1976	C	175	174	0.994	129	0.737	112	0.640	76	0.434
NOV 1976	C	523	416	0.795	370	0.707	318	0.608	300	0.574
	I-4	181	84	0.464	47	0.260	39	0.215	34	0.188
DEC 1976	C	1,745	1,361	0.780	1,150	0.659	1,056	0.605	964	0.552
	I-2	704	544	0.773	345	0.490	283	0.402	206	0.293
JAN 1977	C	96	79	0.823	45	0.469	32	0.333	24	0.250
FEB 1977	C	1,469	1,218	0.829	894	0.609	606	0.412	432	0.294
MAR 1977	C	55	33	0.600	12	0.218	10	0.182	7	0.127
	I-4	178	154	0.865	81	0.455	49	0.275	14	0.079
APR 1977	C	105	68	0.648	22	0.209	15	0.143	10	0.095
DEC 1977	I-2	582	535	0.919	254	0.436	152	0.261	111	0.191
	I-4	578	459	0.794	134	0.232	72	0.125	56	0.097
	C	463	370	0.799	239	0.516	201	0.434	181	0.391
JAN 1978	I-2	231	225	0.974	71	0.307	39	0.169	20	0.086
	I-4	182	100	0.549	18	0.099	11	0.060	5	0.027
	C	171	154	0.900	116	0.678	80	0.468	58	0.339
FEB 1978	I-2	42	34	0.809	11	0.262	11	0.262	5	0.119
	I-4	24	12	0.500	4	0.167	2	0.833	0	0
	C	103	89	0.864	32	0.311	23	0.223	12	0.116
APR 1978	I-2	297	224	0.754	141	0.475	124	0.417	112	0.377
	I-4	281	157	0.559	76	0.270	57	0.203	47	0.167
	C	823	678	0.824	546	0.663	476	0.578	430	0.522

(a) C = continuous; I-2 = intermittent 2-hour hold; I-4 = intermittent 4-hour hold.

(b) Proportion surviving = (live + stunned)/initial number alive.

TABLE C-2 WHITE PERCH CONTROL EXTENDED SURVIVAL AT THE BOWLINE POINT PLANT, 1975-1978

Date	Life Stage(a)	Duration (Minutes)	Initial Number Alive	Proportion Surviving(b)			
				12 Hour	24-36 Hour	48-60 Hour	96-108 Hour
DEC 1975	YOY	30	5	1.000±0.0	1.000±0.0	1.000±0.0	1.000±0.0
NOV 1976	YOY	20	29	0.483±0.093	0.483±0.093	0.414±0.091	0.276±0.830
	YOY	30	36	0.861±0.058	0.722±0.075	0.667±0.078	0.667±0.078
DEC 1976	YOY	10	103	0.524±0.049	0.330±0.046	0.301±0.045	0.214±0.040
	YOY	30	120	0.633±0.044	0.475±0.046	0.433±0.045	0.342±0.043
JAN 1977	Y	30	68	0.573±0.060	0.368±0.058	0.338±0.057	0.250±0.052
FEB 1977	Y	30	94	0.585±0.051	0.404±0.051	0.298±0.047	0.202±0.041
MAR 1977	Y	1	49	1.000±0.0	0.796±0.058	0.592±0.070	0.408±0.070
	Y	15	46	1.000±0.0	0.652±0.070	0.261±0.065	0.196±0.058
	Y	30	48	1.000±0.0	0.562±0.072	0.417±0.071	0.312±0.067
	Y	0	42	1.000±0.0	0.595±0.076	0.452±0.077	0.381±0.075
APR 1977	Y	30	23	0.522±0.104	0.348±0.099	0.217±0.086	0.130±0.070
DEC 1977	YOY	0	127	0.937±0.022	0.882±0.029	0.874±0.029	0.795±0.036
	YOY	1	27	0.926±0.050	0.926±0.050	0.926±0.050	0.815±0.075
	YOY	20	93	0.860±0.036	0.710±0.047	0.602±0.051	0.548±0.052
	YOY	30	66	0.742±0.054	0.651±0.059	0.576±0.061	0.379±0.060
JAN 1978	Y	1	25	0.880±0.065	0.720±0.090	0.720±0.090	0.320±0.093
	Y	15	30	0.967±0.033	0.833±0.068	0.800±0.073	0.500±0.091
	Y	30	25	0.920±0.054	0.720±0.090	0.640±0.096	0.160±0.073
FEB 1978	Y	30	5	0.400±0.219	0.400±0.219	0.200±0.179	0.200±0.179
APR 1978	Y	0	89	0.955±0.022	0.865±0.036	0.831±0.040	0.800±0.042
	Y	1	94	1.000±0.0	1.000±0.0	1.000±0.0	0.915±0.029
	Y	15	121	0.760±0.039	0.661±0.043	0.603±0.044	0.570±0.045
	Y	30	217	0.728±0.030	0.548±0.034	0.488±0.034	0.415±0.033
MAY 1978	Y	1	66	1.000±0.0	0.833±0.046	0.803±0.049	0.712±0.056
	Y	15	48	1.000±0.0	0.937±0.035	0.833±0.054	0.604±0.071
	Y	30	80	1.000±0.0	0.800±0.045	0.762±0.048	0.537±0.056

(a) Y = yearling; YOY = young of the year.

(b) Proportion surviving (normalized) = (live + stunned)/initial number alive; values indicate survival ± 1 standard error.

TABLE C-3 PROPORTION OF WHITE PERCH SURVIVING DURING LONG-TERM EXTENDED HOLDING AT THE BOWLINE POINT PLANT, 1978

	Screen Operating Mode[a]	Number Collected	Initial Number Alive	Proportion Surviving[b]							
				12 Hour	36 Hour	60 Hour	108 Hour	132 Hour	156 Hour	180 Hour	204 Hour
APR	C	793	769	0.854±0.013	0.689±0.017	0.603±0.018	0.546±0.018	0.489±0.018	0.447±0.018	0.402±0.018	0.397±0.018
	I-2	117	101	0.891±0.035	0.364±0.048	0.228±0.042	0.188±0.039	0.158±0.037	0.158±0.036	0.139±0.034	0.109±0.035
	I-4	164	146	0.651±0.039	0.247±0.036	0.157±0.030	0.089±0.024	0.048±0.018	0.048±0.018	0.041±0.016	0.034±0.015
	CNTR (Hold)	89	89	0.955±0.022	0.865±0.036	0.831±0.040	0.798±0.043	0.798±0.043	0.775±0.044	0.708±0.048	0.674±0.050
	CNTR (1 min)	94	94	1.000±0.0	0.979±0.015	0.957±0.020	0.915±0.029	0.862±0.036			
	CNTR (30 min)	93	93	0.989±0.011	0.935±0.026	0.882±0.033	0.763±0.044	0.699±0.046			
MAY	CNTR (1 min)	66	66	--[c]	0.833±0.046	0.803±0.049	0.712±0.056	0.667±0.058	0.667±0.058	0.606±0.060	
	CNTR (15 min)	48	48	--	0.937±0.035	0.833±0.054	0.604±0.071	0.521±0.072	0.458±0.072	0.375±0.070	
	CNTR (30 min)	80	80	--	0.800±0.045	0.762±0.048	0.537±0.056	0.462±0.056	0.412±0.055	0.387±0.054	

(a) C = continuous; I-2 = intermittent 2-hour hold; I-4 = intermittent 4-hour hold; CNTR = control.
(b) Proportion surviving = live + stunned/initial no. alive; ± standard error.
(c) Dashes indicate no observation made.

TABLE C-3 (CONT.)

	Screen Operating Mode[a]	Number Collected	Initial Number Alive	Proportion Surviving[b] 228 Hour	252 Hour	276 Hour	300 Hour	324 Hour
APR	C	793	769	0.363±0.017	0.320±0.017	0.285±0.016	0.247±0.015	0.077±0.010
	I-2	117	101	0.079±0.027	0.079±0.027	0.069±0.025	0.040±0.019	0.040±0.019
	I-4	164	146	0.034±0.015	0.034±0.015	0.034±0.015	0.027±0.014	0.007±0.007
	CNTR (Hold)	89	89	0.371±0.051	0.371±0.051	0.202±0.043	0.146±0.037	

(a) C = continuous; I-2 = intermittent 2-hour hold; I-4 = intermittent 4-hour hold; CNTR = control.

(b) Proportion surviving = live + stunned/initial no. alive; ± standard error.

TABLE C-4 EXTENDED SURVIVAL FOR STRIPED BASS DURING IMPINGEMENT STUDIES AT THE BOWLINE POINT PLANT BY MONTH, 1975-1978

			Time of Observation							
			12 Hour		24-36 Hour		48-60 Hour		96-108 Hour	
	Screen Condition(a)	Initial Number Alive	No.	Survival Proportion(b)	No.	Survival Proportion	No.	Survival Proportion	No.	Survival Proportion
JAN 1976	C	1	1	1.000	1	1.000	0	0	0	0
FEB 1976	C	30	22	0.733	8	0.267	6	0.200	3	0.100
MAR 1976	C	2	2	1.000	0	0	0	0	0	0
APR 1976	C	8	5	0.625	4	0.500	2	0.250	2	0.250
NOV 1976	C	3	2	0.667	2	0.667	2	0.667	2	0.667
DEC 1976	CNTR	30	20	0.667	8	0.267	7	0.233	5	0.167
	I-2	124	91	0.734	46	0.371	39	0.314	31	0.250
	C	205	169	0.824	140	0.683	121	0.590	112	0.546
JAN 1977	CNTR	2	1	0.500	1	0.500	1	0.500	1	0.500
	C	31	28	0.903	18	0.581	13	0.419	10	0.323
FEB 1977	C	505	470	0.931	364	0.721	228	0.451	166	0.329
MAR 1977	CNTR	6	6	1.000	4	0.667	3	0.500	2	0.333
	I-4	106	99	0.934	21	0.198	5	0.047	2	0.019
	C	19	7	0.368	2	0.105	0	0	0	0
APR 1977	CNTR	4	4	1.000	2	0.500	1	0.250	0	0
	C	12	7	0.583	5	0.417	3	0.250	2	0.167
DEC 1977	CNTR	1	1	1.000	1	1.000	1	1.000	0	0
	I-2	15	10	0.667	6	0.400	4	0.267	2	0.133
	I-4	17	11	0.647	5	0.294	3	0.176	3	0.176
	C	2	2	1.000	2	1.000	1	0.500	1	0.500
JAN 1978	CNTR	1	0	0	0	0	0	0	0	0
	I-2	1	1	1.000	0	0	0	0	0	0
	I-4	5	0	0	0	0	0	0	0	0
	C	14	14	1.000	9	0.643	8	0.571	4	0.286
FEB 1978	I-2	10	9	0.900	2	0.200	1	0.100	1	0.100
	I-4	8	4	0.500	1	0.125	1	0.125	0	0
	C	15	11	0.733	5	0.333	1	0.067	0	0
APR 1978	CNTR	29	18	0.621	12	0.414	11	0.379	11	0.379
	I-2	50	18	0.360	14	0.280	12	0.240	9	0.180
	I-4	51	8	0.157	5	0.098	3	0.059	3	0.059
	C	130	47	0.361	30	0.231	26	0.200	22	0.169
MAY 1978	CNTR	4	4	1.000	1	0.250	1	0.250	0	0

(a) C = continuous; CNTR = control; I-2 = intermittent 2-hour hold; I-4 = intermittent 4-hour hold.

(b) Survival proportion = (no. live + no. stunned)/initial no. alive.

TABLE C-5 EXTENDED SURVIVAL FOR STRIPED BASS DURING IMPINGEMENT STUDIES AT THE BOWLINE POINT PLANT BY SEASONAL MONTH GROUP, 1975-1978

			Time of Observation							
			12 Hour		24-36 Hour		48-60 Hour		96-108 Hour	
	Screen Condition(a)	Initial Number Alive(b)	No.	Survival Proportion(c)	No.	Survival Proportion	No.	Survival Proportion	No.	Survival Proportion
NOV-DEC	C	210	173	0.824±0.017(d)	144	0.686±0.032	124	0.590±0.034	115	0.548±0.034
	I-2	139	101	0.727±0.038	52	0.374±0.041	43	0.309±0.039	33	0.237±0.036
	I-4	17	11	0.647±0.116	5	0.294±0.111	3	0.176±0.092	3	0.176±0.092
JAN-FEB	C	596	577	0.968±0.007	405	0.679±0.019	256	0.429±0.020	183	0.307±0.019
	I-2	11	10	0.909±0.087	2	0.182±0.116	1	0.091±0.087	1	0.091±0.087
	I-4	13	4	0.308±0.128	1	0.077±0.074	1	0.077±0.074	0	0
MAR-APR	C	172	68	0.395±0.037	41	0.238±0.032	31	0.180±0.029	26	0.151±0.027
	I-2	50	18	0.360±0.068	14	0.28 ±0.063	12	0.24 ±0.060	9	0.18 ±0.054
	I-4	157	107	0.681±0.037	26	0.166±0.030	8	0.051±0.017	5	0.032±0.014

(a) C = continuous; I-2 = intermittent 2-hour hold; I-4 = intermittent 4-hour hold.

(b) Alive refers to live + stunned.

(c) Survival proportion = (live + stunned)/initial no. alive.

(d) Proportion surviving ± standard error.

TABLE C-6 EXTENDED SURVIVAL FOR HOGCHOKER, RAINBOW SMELT, AND ATLANTIC TOMCOD IN IMPINGEMENT SURVIVAL STUDIES AT THE BOWLINE POINT PLANT

	Screen Operating Mode(a)	Initial Number Alive(b)	Proportion Surviving(c)			
			Time of Observation (hr)			
			12	24-36	48-60	96-108
Hogchoker	I-4	124	1.000±0.0	1.000±0.0	1.000±0.0	0.831±0.034
Rainbow smelt	C	530	0.353±0.021	0.207±0.018	0.147±0.015	0.038±0.008
	I-2	137	0.562±0.042	0.248±0.037	0.117±0.027	0.015±0.010
	I-4	101	0.228±0.042	0.079±0.027	0.040±0.019	0.020±0.014
Atlantic tomcod	C	111	0.955±0.020	0.955±0.020	0.946±0.021	0.901±0.028
	I-2	8	1.000±0.0	1.000±0.0	1.000±0.0	1.000±0.0
	I-4	5	1.000±0.0	1.000±0.0	0.800±0.179	0.600±0.219

(a) C = continuous; I-2 = intermittent 2-hour hold; I-4 = intermittent 4-hour hold.

(b) Alive includes all live and stunned organisms.

(c) Proportion surviving (normalized) = (live + stunned)/initial no. alive; ± 1 standard error.

APPENDIX D

DATA USED IN THE ANALYSIS OF PHYSICOCHEMICAL VARIABLES AND IMPINGEMENT SURVIVAL AT THE BOWLINE POINT PLANT, 1975-1978

TABLE D-1 WHITE PERCH DATA USED FOR LINEAR REGRESSION ANALYSIS OF RELATIONSHIP BETWEEN PHYSICOCHEMICAL VARIABLES AND SURVIVAL

Date(a)	Mean Conductivity(b) (μmho)	Conductivity (ln[x])	Mean Water Temperature(b) (C)	Mean Air Temperature(c) (C)	96-108-hr Survival(d)
11 DEC 75	1,013	6.921(e)	5.7	3.2	0.952
17 FEB 76	159	5.069	3.1(f)	3.0	0.355
29 MAR 76	133	4.890(e)	7.3	8.7	0.073
1 APR 76	139	4.934(e)	8.1	4.5	0.079
15 APR 76	615	6.422(e)	10.3	16.7	0.617
1 NOV 76	137	4.920(e)	9.6	0.6	0.145
8 NOV 76	127	4.844(e)	7.1	-3.4	0.434
15 NOV 76	499	6.213(e)	7.3	0.6	0.644
2 DEC 76	1,026	6.933(e)	4.0(f)	-8.3	0.683
6 DEC 76	668	6.504(e)	4.1(f)	0.8	0.773
13 DEC 76	368	5.908	1.7(f)	-12.9	0.155
27 JAN 77	1,958	7.580	0.9(f)	-6.8	0.114
3 FEB 77	1,961	7.581	1.2(f)	-0.2	0.187
10 FEB 77	2,089	7.644	1.9(f)	-0.7	0.189
24 FEB 77	1,413	7.253	2.9(f)	6.2	0.343
24 MAR 77	155	5.043(e)	4.9	-4.8	0.096
7 APR 77	128	4.852(e)	7.4	4.4	0.082
7 DEC 77	1,570	7.359	3.4(f)	-5.3	0.588
14 DEC 77	390	5.966(e)	3.6(f)	4.4	0.317
19 JAN 78	396	5.981	1.2(f)	-4.4	0.0
26 JAN 78	772	6.649	2.1(f)	-4.0	0.356

(a) Includes dates when total number collected was >10.

(b) Average of values between 0 and 108 hours.

(c) Average of initial values.

(d) (no. live + no. stunned)/(no. live + no. stunned + no. dead).

(e) Used in analysis group when temperatures were >4.5 C.

(f) Used in analysis group when temperatures were <4.5 C.

TABLE D-1 (CONT.)

Date[a]	Mean Conductivity[b] (µmho)	Conductivity (ln[x])	Mean Water Temperature[b] (C)	Mean Air Temperature[c] (C)	96-108-hr Survival[d]
2 FEB 78	96	4.564	1.0[f]	-8.9	0.109
9 FEB 78	179	5.187	1.2[f]	-7.2	0.097
6 APR 78	110	4.700[e]	6.5	6.9	0.098
13 APR 78	133	4.890[e]	9.2	11.5	0.167
20 APR 78	2,540	7.840[e]	8.4	8.1	0.922
27 APR 78	533	6.278[e]	11.2	7.2	0.545

(a) Includes dates when total number collected was >10.
(b) Average of values between 0 and 108 hours.
(c) Average of initial values.
(d) (no. live + no. stunned)/(no. live + no. stunned + no. dead).
(e) Used in analysis group when temperatures were >4.5 C.
(f) Used in analysis group when temperatures were <4.5 C.

TABLE D-2 WHITE PERCH CONTROL DATA USED FOR LINEAR REGRESSION ANALYSIS OF RELATIONSHIP BETWEEN PHYSICOCHEMICAL VARIABLES AND SURVIVAL

Date(a)	Mean Conductivity(b)	Conductivity [ln(x)]	Mean Water Temperature(b)	98-108-hr Survival(c)
8 NOV 76	132	4.883(d)	7.2	0.656
2 DEC 76	1,026	6.933(d)	4.0(e)	1.00
6 DEC 76	660	6.492(d)	4.0(e)	0.429
7 DEC 76	602	6.400(d)	4.1(e)	0.091
13 DEC 76	384	5.951	2.0(e)	0.159
27 JAN 77	1,976	7.589	1.1(e)	0.250
3 FEB 77	1,960	7.581	0.7(e)	0.182
10 FEB 77	2,130	7.664	2.5(e)	0.294
31 MAR 77	426	6.054(d)	6.6	0.312
7 APR 77	130	4.867(d)	7.6	0.130
7 DEC 77	1,560	7.352	3.3(e)	0.286
14 DEC 77	380	5.940(d)	3.6(e)	0.484
26 JAN 78	910	6.813	2.0(e)	0.040
6 APR 78	109	4.961(d)	6.5	0.207
13 APR 78	132	4.883(d)	9.0	0.027
20 APR 78	2,540	7.840(d)	8.4	1.00
27 APR 78	532	6.277(d)	11.3	0.562

(a) Includes dates when total number collected was > 10.

(b) Average of values from 0 to 108 hours.

(c) (no. live + no. stunned)/(no. live + no. stunned + no. dead).

(d) Used in analysis group when water temperatures were > 4.5 C.

(e) Used in analysis group when water temperatures were < 4.5 C.

TABLE D-3 STRIPED BASS DATA USED FOR LINEAR REGRESSION ANALYSIS OF RELATIONSHIP BETWEEN PHYSICOCHEMICAL VARIABLES AND SURVIVAL

Date(a)	Mean Conductivity(b)	Conductivity ln(x)	Mean Water Temperature(b)	98-108-hr Survival(c)
17 FEB 76	159	5.069	3.1(d)	0.100
2 DEC 76	1,026	6.933(e)	4.0(d)	0.906
6 DEC 76	668	6.504(e)	4.1(d)	0.814
13 DEC 76	368	5.908	1.7(d)	0.139
27 JAN 77	1,958	7.580	0.9(d)	0.192
3 FEB 77	1,961	7.581	1.2(d)	0.172
10 FEB 77	2,089	7.644	1.9(d)	0.220
24 FEB 77	1,413	7.253	2.9(d)	0.407
24 MAR 77	155	5.043(e)	4.9	0
7 APR 77	128	4.852(e)	7.4	0.118
26 JAN 78	772	6.648	1.4(d)	0.333
6 APR 78	110	4.700(e)	6.5	0.014
13 APR 78	133	4.890(e)	9.2	0
20 APR 78	2,540	7.840(e)	8.4	0.536
27 APR 78	533	6.279(e)	11.2	0.316

(a) Includes dates when total number collected was > 10.
(b) Average of values from 0 to 108 hours.
(c) (no. live + no. stunned)/(no. live + no. stunned + no. dead).
(d) Used in analysis group when temperatures were < 4.5 C.
(e) Used in analysis group when temperatures were > 4.5 C.

TABLE D-4 WHITE PERCH HOLDING CONTROL DATA USED FOR LINEAR REGRESSION ANALYSIS OF RELATIONSHIP BETWEEN PHYSICOCHEMICAL VARIABLES AND SURVIVAL

Date(a)	Mean Conductivity(b)	Conductivity ln(x)	Mean Water Temperature(b)	98-108-hr Survival(c)
31 MAR 77	426	6.054	6.6	0.786
7 DEC 77	1,560	7.352	3.3	0.893
8 DEC 77	1,700	7.438	3.0	0.957
14 DEC 77	380	5.940	3.6	0.667
15 DEC 77	280	5.635	3.3	0.788
16 DEC 77	280	5.635	3.1	0.640
20 APR 78	2,540	7.840	8.4	1.00
27 APR 78	532	6.277	11.3	0.833

(a) Includes dates when total number collected was > 10.

(b) Average of values from 0 to 108 hours.

(c) (no. live + no. stunned)/(no. live + no. stunned + no. dead).

APPENDIX E

SUMMARY OF NUMERICAL DIFFERENCES BETWEEN PREVIOUS REPORTS AND THE DATA BASE USED IN THIS REPORT

TABLE E-1 NUMBER OF IMPINGED WHITE PERCH COLLECTED COMPARED WITH PREVIOUS PUBLICATIONS

		Initial Number				Initial Number Alive for Subsample	
Date	Wash Mode	EA 1977, ORU 1977	Corrections to EA 1977, ORU 1977	King et al. 1978	Computer Final	King et al. 1978	Computer Final
1976							
JAN	C-H	7	--		7		
FEB	C-H	31	--		31		
MAR	C-H	55	--		55		
APR	C-H	221(a)	178		178		
NOV	C	557(b)	575(c)		570		
	I-4	237(b)	257(d)		254		
DEC	C	5,313(b)	5,312		5,312		
	I-2	2,383	--				
NOV-DEC	C	5,870(b)	5,887(c)		5,882	2,253	2,268
	I-2	2,383	--	2,383	2,383	705(b)	704
	I-4	237(b)	257(d)	254	254	181	181
1977							
JAN-MAR	C			1,855	1,929(f)		

(a) Includes 43 fish from tagging mortality study.
(b) Numerical error in original data analysis.
(c) Includes 5 adults.
(d) Includes 3 adults.
(e) Includes 18 fish originally classified as yearling.

TABLE E-2 NUMBER OF IMPINGED STRIPED BASS COLLECTED COMPARED WITH PREVIOUS PUBLICATIONS

		Initial Number				Initial Number Alive for Subsample	
Date	Wash Mode	EA 1977, ORU 1977	Corrections to EA 1977, ORU 1977	King et al. 1978	Computer Final	King et al. 1978	Computer Final
1976							
JAN	C-H	4(a)	--		3(b)		
FEB	C-H	31(a)	--		30		
MAR	C-H	3	--		3		
APR	C-H	7	--		7		
NOV	C	5	--		5		
DEC	C	412(a)	438	412(a)	438	393(c)	205
	I-2	269	--	256(a)	269	237(c)	124
1977							
JAN-MAR	C			617(a)	628		

(a) Numerical error in original data analysis.

(b) Includes one yearling and two age groups II.

(c) Subsampling not taken into account in original analysis.

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BOWLINE POINT GENERATING STATION
HYDROTHERMAL ANALYSES
MARCH 1978

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ORANGE AND ROCKLAND UTILITIES, INC.
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BOWLINE POINT GENERATING STATION

HYDROTHERMAL ANALYSIS

ORANGE AND ROCKLAND UTILITIES, INC.

ONE BLUE HILL PLAZA
PEARL RIVER, N.Y. 10965

March 1978

LAWLER, MATUSKY & SKELLY ENGINEERS
Environmental Science & Engineering Consultants
ONE BLUE HILL PLAZA
PEARL RIVER, N.Y. 10965

BOWLINE POINT GENERATING STATION

HYDROTHERMAL ANALYSIS

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (CONT)

LIST OF FIGURES

LIST OF FIGURES (CONT)

LIST OF FIGURES (CONT)

LIST OF TABLES

SUMMARY OF CONCLUSIONS

1. Field studies best represent the thermal plume from Bowline Point; plume measurements were taken under a wide range of seasons, river conditions and plant capacities, including maximum capacity. The studies indicate the wide variation in the plume and, using the worst-case surveys suggest the following conclusions:

   a. No violation of the New York State thermal criteria regarding maximum surface temperature (90 F), percent surface width (67%), or percent cross-sectional area (50%) is expected to occur (Table 4-9).

   b. The average surface area of the $\geq$4 F (2.2 C) temperature rise isotherm is 4.63 acres. The ratio of this area to the surface area encompassed by one upstream and one downstream tidal excursion is 1:1528. The average volume of the $\geq$4 F (2.2 C) temperature rise isotherm is 26.2 acre-ft. The ratio of this volume to the volume encompassed by one upstream and one downstream tidal excursion is 1:5620. Areal and volumetric dimensions of other boundary isotherms are given in Table 4-3.

   c. The portion of the receiving water body in the vicinity of the Bowline Point discharge which is within the 2 C (3.6 F) temperature rise isotherm 30% or more of the time is approximately 2 acres at the surface.

2. Mathematical model studies used to predict the thermal plume before operation of Bowline Point are generally conservative when compared to the measured field results, i.e., the model predicted higher temperatures and/or larger areas subject to plant-induced temperature rises.

3. Hydraulic model studies used to help design the original diffuser and predict the thermal plume compare favorably with the field studies. Although the model yielded slightly higher average predictions, the field results fell within the range of the model predictions (Table 4-9).
4. Far-field temperature rise from the maximum capacity operation of all plants on the mid-Hudson estuary is 1.6 F at Bowline Point and 0.4 F for the operation of only Bowline Point.
5. The average recirculation at Bowline Point is approximately 13%. The maximum recirculation is 19.8% under full plant flow and narrow winter plume width. Analyses indicates that increased plant flow increases recirculation, although this is not a direct relationship.
6. There is an insignificant DO loss through the plant (0.02 to 1.50 mg/l) which causes no effect on river DO. The operation of the chlorination system at Bowline has no effect on the river.

1. INTRODUCTION

This report is a documentation of the temperature distribution in the Hudson River as it is affected by the operation of the Bowline Point Generating Station. It begins with a brief description of the Bowline Point plant, its location, and the river physics, and continues with a discussion of the field studies and mathematical and hydraulic models which have been used to establish the thermal effects due to the operation of the plant. Field and model studies are also considered as they relate to the New York State thermal criteria.

The zone of discharge (as defined by U.S. EPA) and time-temperature profile are presented. In addition, recirculation is discussed and presented. A short description of the plant's effect on dissolved oxygen in the river and the effect of chlorination is given.

2. PLANT DESCRIPTION

2.1 LOCATION

The Bowline Point Generating Station is located on the west bank of the Hudson River (at milepoint 37.5) in the Town of Haverstraw and Village of W. Haverstraw (Rockland County), New York. Figure 2-1 shows the location of the Bowline Point Generating Station.

2.2 DESCRIPTION

The plant consists of two 600-MW units, each capable of being fired by oil and natural gas. Unit 1 has been in operation since September 1972 and Unit 2 began commercial operation in May 1974.

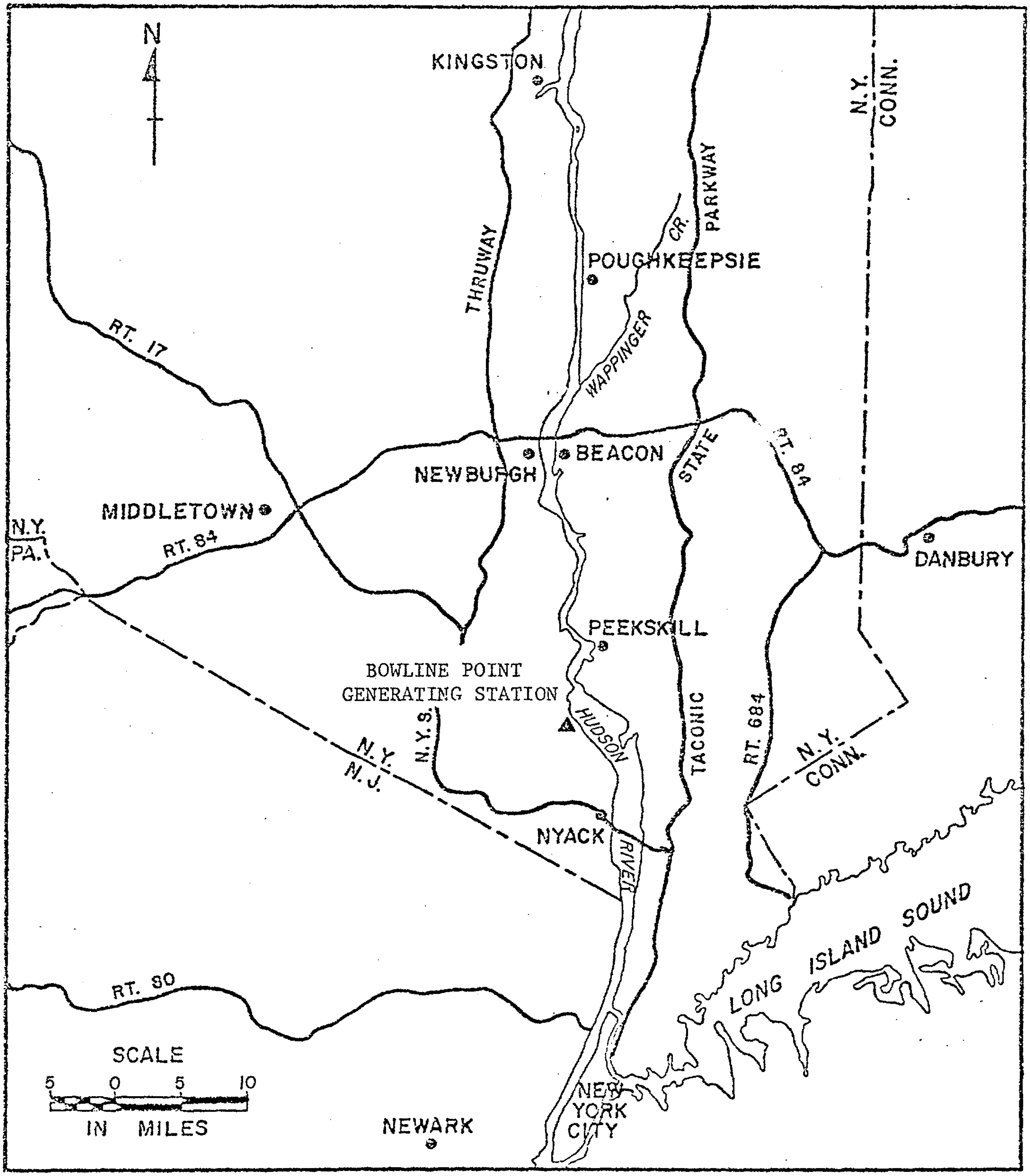
Orange and Rockland Utilities, Incorporated (O&R), and the Consolidated Edison Company of New York own the plant as tenants-in-common, with ownership being one-third and two thirds, respectively. The plant is operated and maintained by O&R.

2.3 DISCHARGE SYSTEM

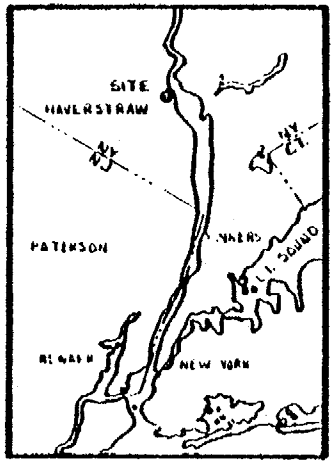
The two diffusers, for Units 1 and 2, are located in the Hudson River approximately 2,500 ft east of the plant, approximately 1,400 ft offshore (Figure 2-2). Each diffuser is steel pipe, 10 ft, 6 inch ID, with a 5/8-inch wall and 220 ft long. Each diffuser contains a total of eight discharge nozzles (Figure 2-3), each 3 ft in diameter at its outlet. All nozzles are angled 5 degrees upward from the horizontal to minimize scouring of the river bottom. A summary of plant operational conditions is given in Table 2-1.

GENERAL LOCATION MAP

BOWLINE POINT GENERATING STATION



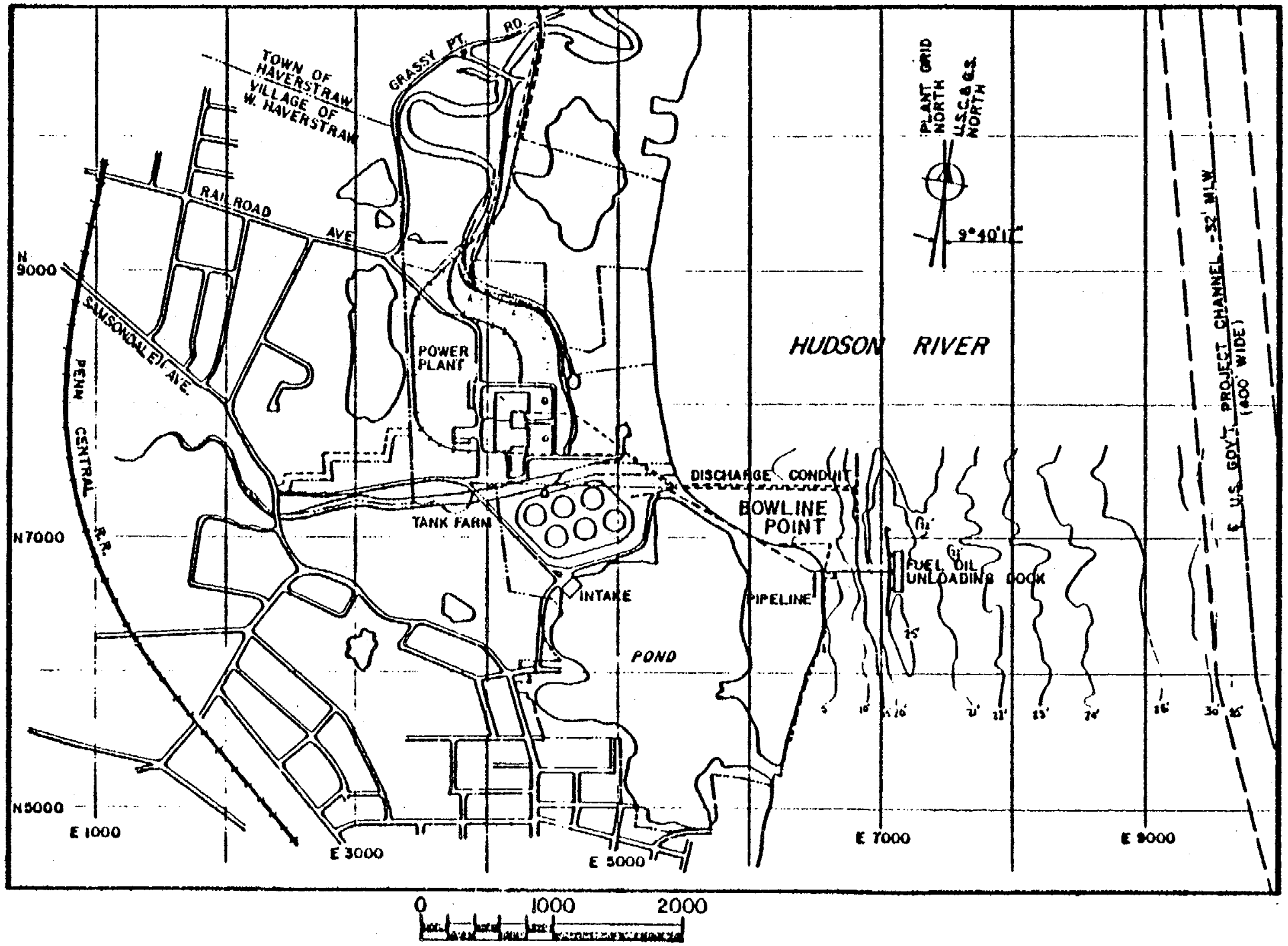
PLANT SITE: BOWLINE POINT GENERATING STATION



LOCATION MAP

SCALE IN MILES

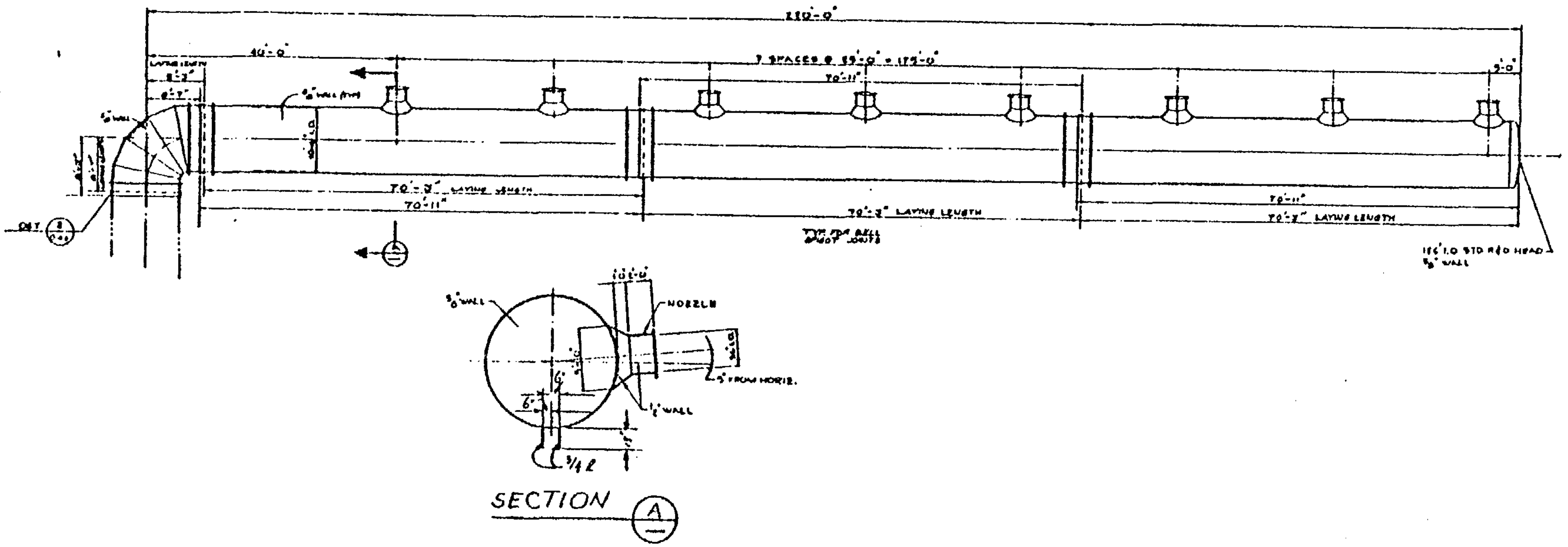
POND SURFACE AREA = 2.35 x 10⁶ ft²



SCALE IN FEET

FIGURE 2-2

FIGURE 2-3



Circulating water discharge header, Bowline Point plant.

TABLE 2-1: PLANT OPERATIONAL DATA BOWLINE POINT GENERATING STATION - 1974

OPERATING CHARACTERISTICS	UNITS 1 & 2 (EACH)
Nominal Net Generating Capacity Rating, MWe	600
Maximum Gross Generating Capacity Rating, MWe	620
Cooling Water Flow Rate (3 pumps) gpm	
Condenser	375,620
Service Water	8,480
Heat Rejection Rate, Btu/Hr	2.82×10^9
Cooling Water Temperature Rise, F	14.9
INTAKE CHARACTERISTICS	
Type of Intake	Shoreline
Maximum Approach Velocity to the Screens, fps	0.77
Pipe Diameter from Intake to Condenser, ft	10.5
Total flow, gpm (cfs)	384,100 (856)
OUTFALL CHARACTERISTICS	
Length of Main Tunnel from Existing Hudson River Shoreline, ft	1,400
Tunnel Velocity, fps	9.9
Length of Diffuser, ft	220
Number of Diffuser Ports	8
Inside Diameter ofDiffuser Ports, ft	3
Port Spacing, ft	25
Initial Jet Velocity, fps	15
Total Diffuser Flow, gpm	384,000
Average Depth of Port Centerline Below Mean Low Water, ft	15
Average Depth to River Bottom Below Mean Low Water, ft	21
Port Temperature Rise Above River Ambient, F	14.9

The final design of a submerged diffuser was chosen after extensive study indicated that such a design would provide maximum dilution of the thermal discharge.

2.4 COOLING WATER FLOW CHARACTERISTICS

Three circulating water pumps are associated with each unit, and there are three acceptable modes of operation, since at least two pumps must be running to permit reliable and safe operation of a unit. Based on the circulating water pump characteristic curves and the circulating water system head loss curves (shown in Figure 2-4), the following table summarizes the cooling water system flows and the total dynamic head (TDH) associated with the four possible modes of operation:

	Cooling Water Rate per Unit			
No. of Pumps	Per Minute (gpm)	Per Hour (gph)	Per Day (gpd)	TDH (ft)
3	384,000	23,040,000	552,960,000	35
2	316,000	18,960,000	455,040,000	22.4
2 (throttled)	257,000	15,420,000	370,080,000	35
1	185,000	11,100,000	266,400,000	10.4

The above table also demonstrates that each circulating water pump tends to pump more water as the total system flow and head losses decrease. During the warmest months, the last two weeks in June through the first two weeks in September, three pumps are run to keep temperature rise across the condenser and river temperature rise to a minimum. For the remainder of the year, only two pumps are run to meet all operating requirements. Under restrictive operating constraints for aquatic studies, the circulating water system has been operated with two pumps running and the condenser discharge valve throttled to reduce system flows to a minimum without jeopardizing generating system

CIRCULATING WATER SYSTEM PERFORMANCE CURVES
BOWLINE POINT PLANT GENERATING STATION

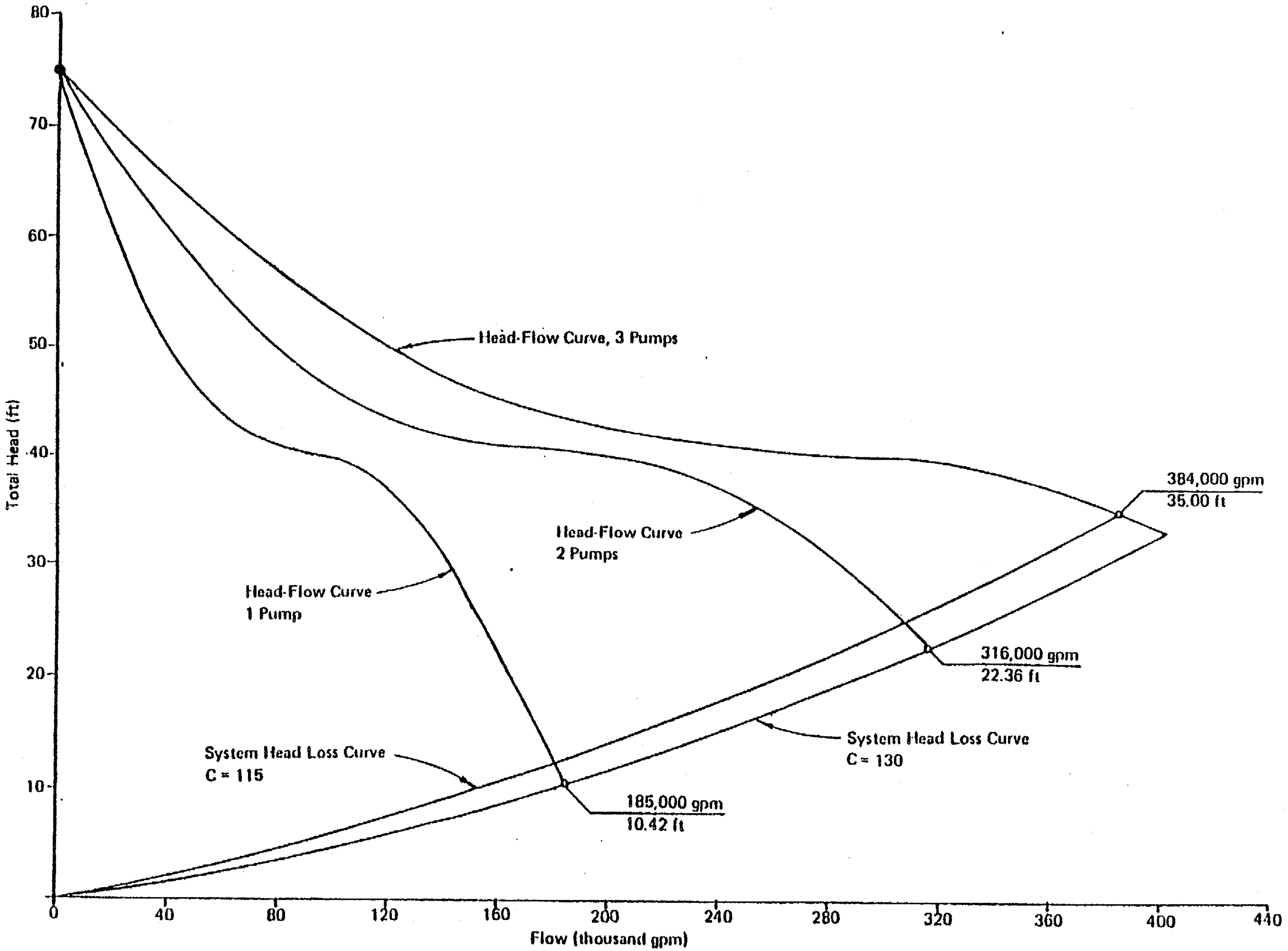


FIGURE 2-4

reliability. Although the two-pump-throttled mode of operation is not optimal from an operating point of view, it is an operating option available to reduce river water flow through the system during the cooler months of the year.

2.5 HEAT REJECTION

Electricity is the product of power imparted to the turbine-generator system by steam that has been produced in the boiler by the burning of oil or gas. The thermal cycle of a steam electric generating plant requires the rejection of all heat in the boiler that is not converted to electricity by the turbine-generator system.

The condenser heat transfer system completes the thermal cycle by cooling the spent steam that has passed through the turbine to a liquid for re-entry into the boiler by the feedwater pumps. The mode of heat rejection required for a given energy input varies somewhat with the ambient air temperature. During the colder winter months, steam heat is utilized to preheat air and oil before entry into the boiler. At this time, although the plant must essentially reject the same amount of heat, a greater portion of the total rejected heat is emitted to the air and a correspondingly smaller portion to the cooling water. During the warmer summer months, air and oil preheating are at a minimum, resulting in a greater heat rejection to the cooling water.

The heat rejection rates for the various modes of pump operation for the months of April-August were calculated in the following manner:

$$\begin{aligned}\text{Heat Rejected (Btu/hr)} = {} & \text{Mass Flow (lb/hr)} \\ & \times \text{ Specific Heat of } H_2O \text{ (Btu/lb.F)} \\ & \times \text{ delta-T (F).}\end{aligned}$$

Figures 2-5 through 2-7 show heat rejection versus net megawatt output. These graphs were calculated using linear regression analysis methods applied to actual temperature changes across the condenser and the associated flow rates. Due to the minimum flow limitations for boiler feedwater, the generators are not operated on a continuous basis below approximately 150 MW. The graphs indicate actual heat rejection rates for the normal operating range of the generator, 150 to 600 MW. They do not show heat rejection rates under startup conditions.

2.5.1 Temperature Profiles

The rise in cooling water temperature is inversely proportional to the rate of cooling water flow and directly proportional to the rate of heat rejection (which itself is a function of the megawatt output). Based upon actual temperature data, curves of delta-T versus net megawatt output (See Figure 2-8) were calculated using methods of linear regression analysis.

2.5.2 Maximum Discharge Temperature Rises

For purposes of evaluating the effects of the discharge, the maximum discharge temperature rises were estimated over the year. Using the relationships in Figure 2-8, maximum plant load, a recirculation rate of 13% (see Chapter 7), and a typical pumping schedule, the maximum discharge temperature rise from Bowline Point is 14.8 F (8.2 C) during the period from 15 June to 15 September and 18.1 F (10.0 C) during the period from 16 September to 14 June.

Although the developed relationships (Figure 2-8) are based on spring-summer plant operation, they can be used as a conservative estimate for the whole year; during the winter the plant discharges less total heat to the river.

HEAT REJECTION RATE VS. NET GENERATION WITH
A CIRCULATING WATER FLOW OF 384,000 gpm
BOWLINE POINT GENERATING STATION - APRIL-AUGUST

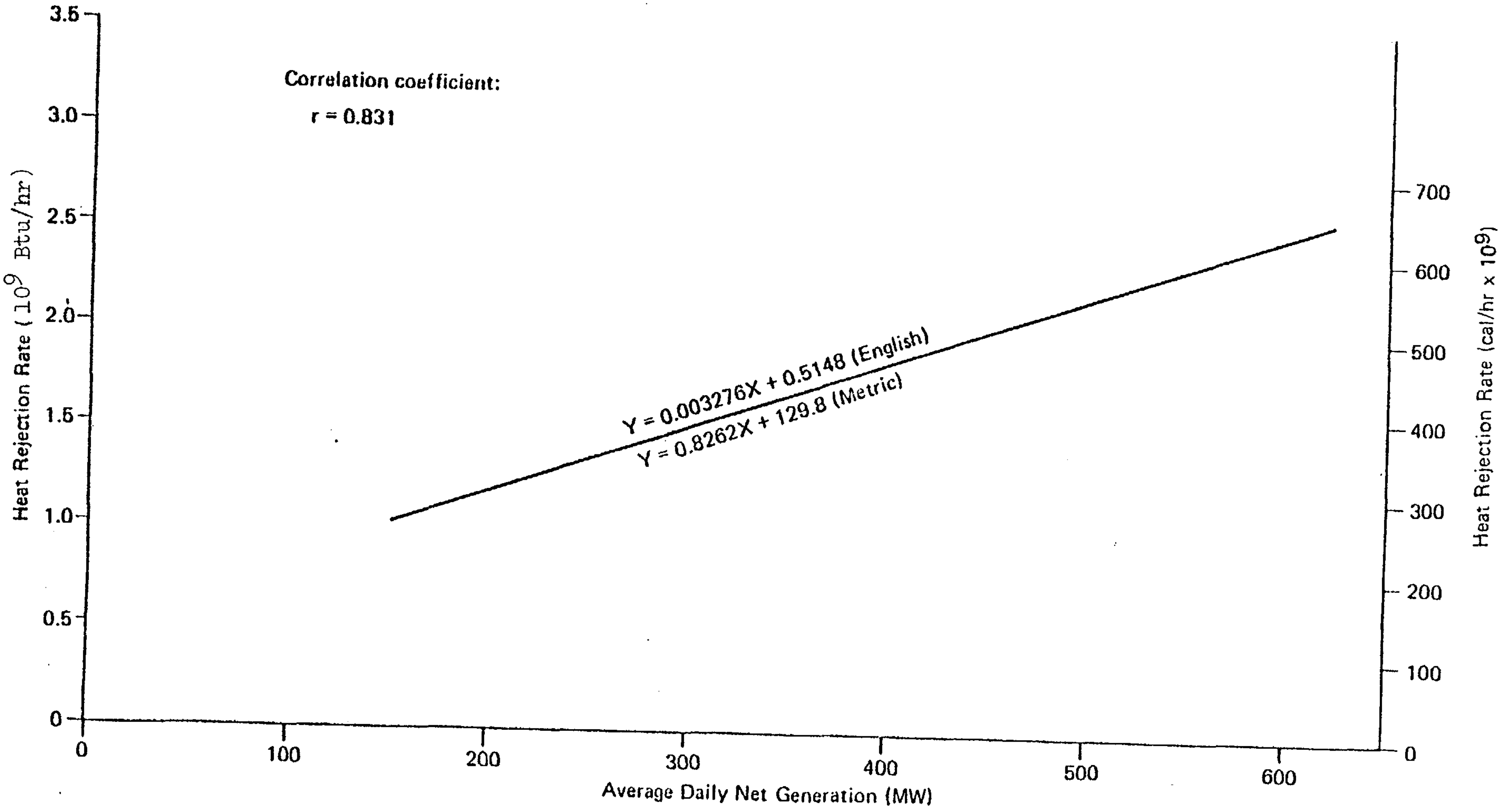


FIGURE 2-5

HEAT REJECTION RATE VS. NET GENERATION WITH
A CIRCULATING WATER FLOW OF 316,000 gpm
BOWLINE POINT GENERATING STATION - APRIL-AUGUST

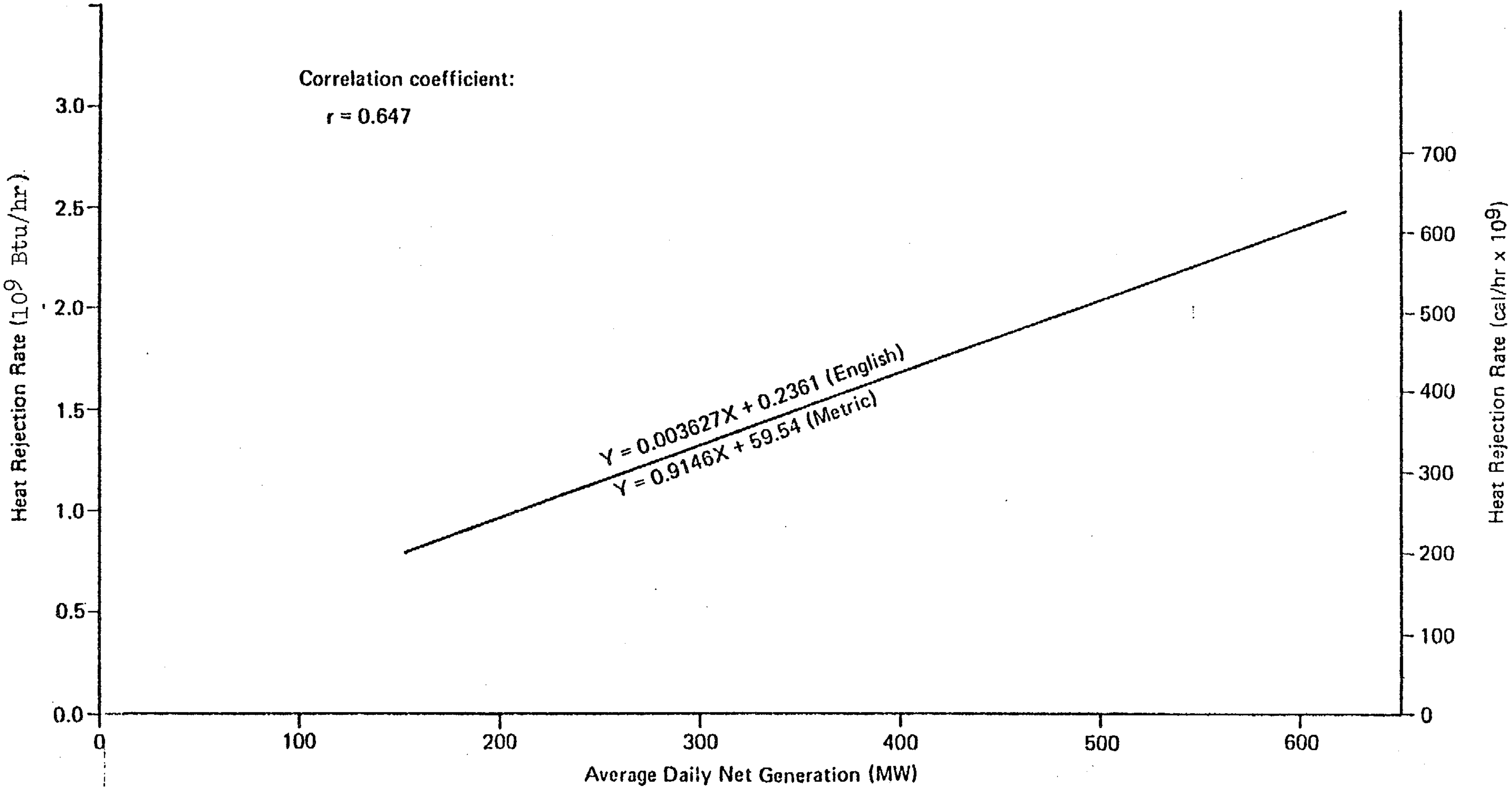


FIGURE 2-6

HEAT REJECTION RATE VS. NET GENERATION WITH A CIRCULATING WATER FLOW OF 257,000 gpm BOWLINE POINT GENERATING STATION - APRIL-AUGUST

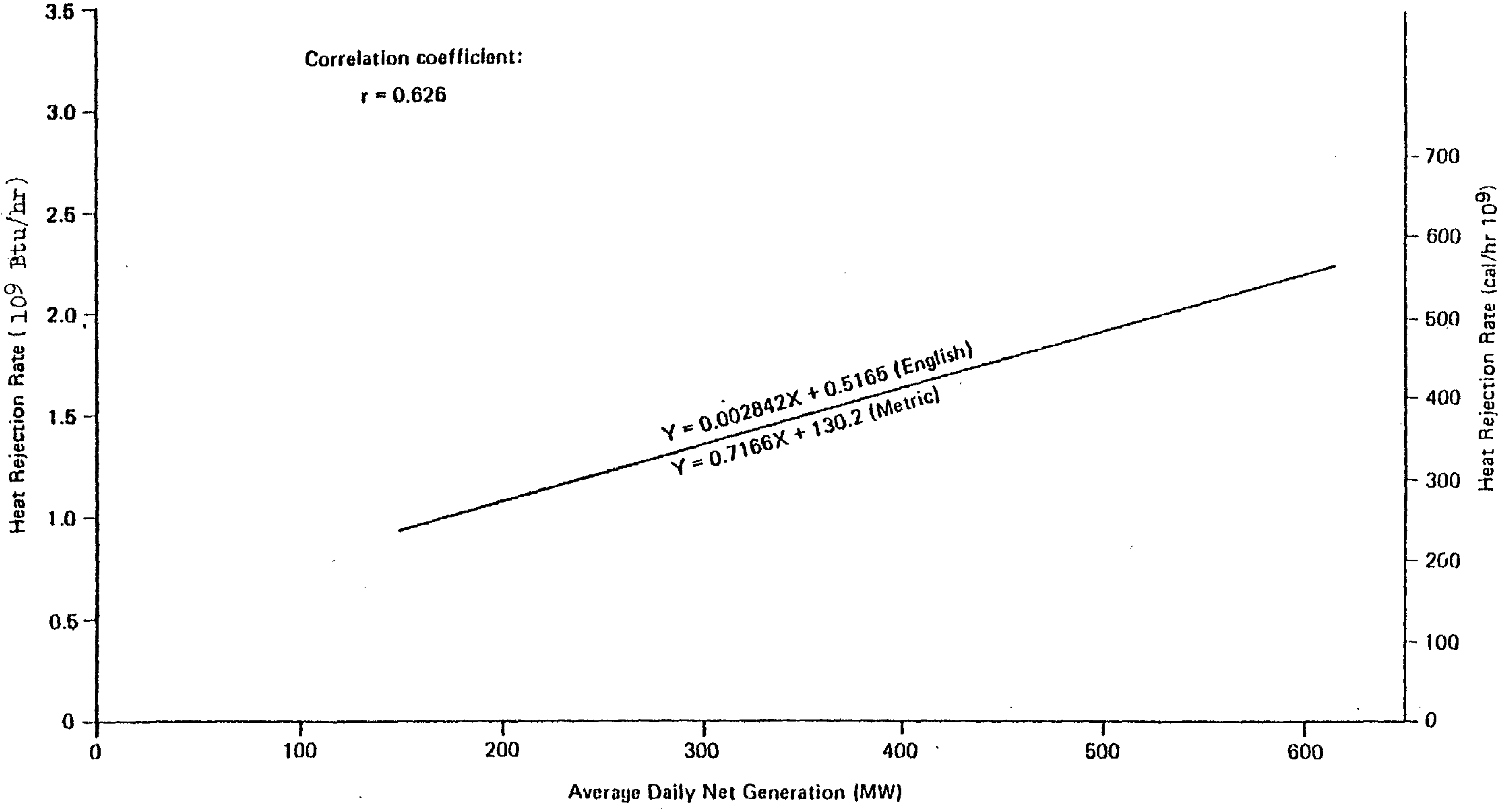


FIGURE 2-7

WATER TEMPERATURE CHANGE VS. DAILY AVERAGE OUTPUT
FOR THREE OPERATING CONDITIONS
BOWLINE POINT GENERATING STATION

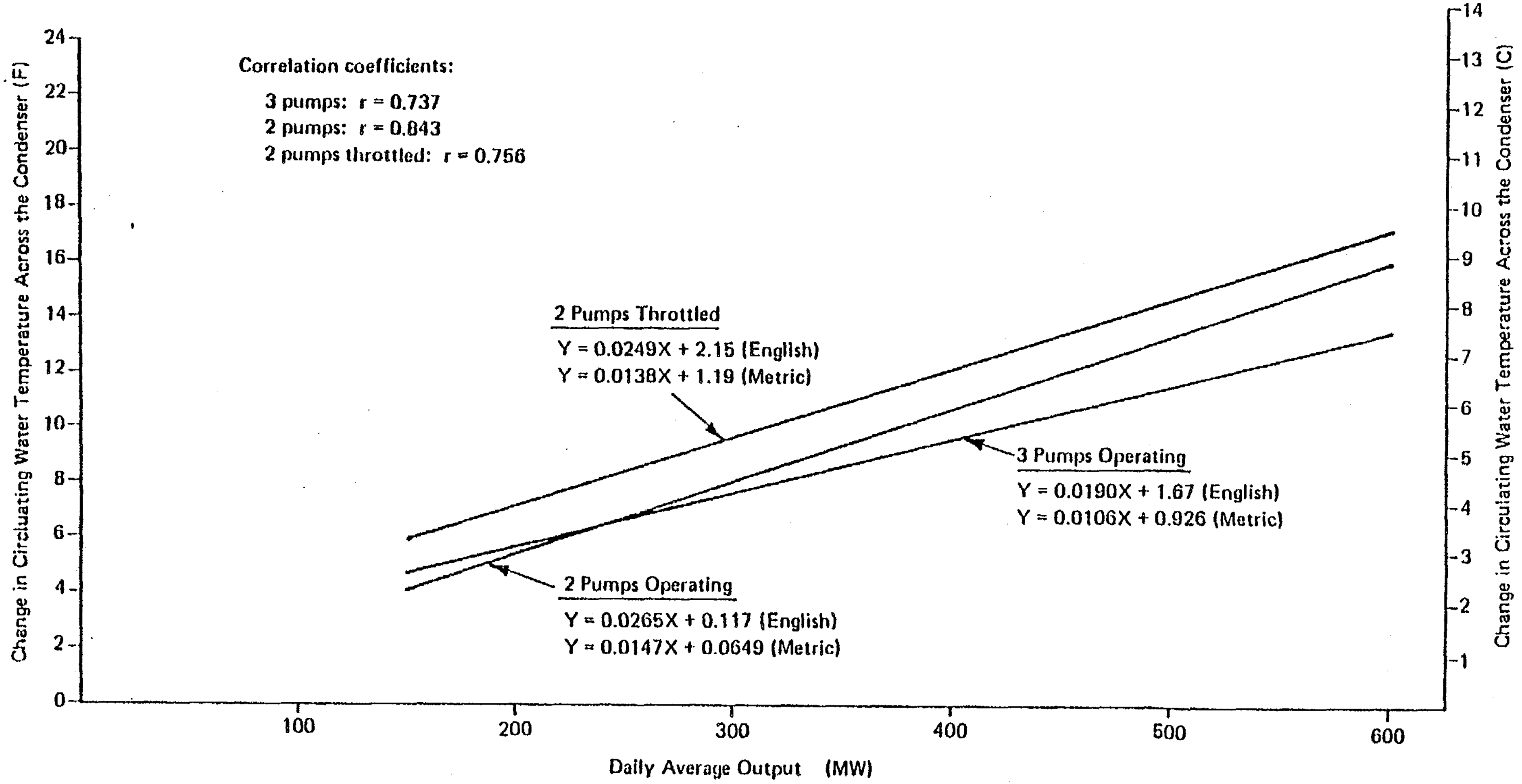


FIGURE 2-8

In addition, these temperature rises are conservative estimates because they are based on the use of maximum plant capacity (600 MWe per Unit), which is far higher than normal average plant capacities (see Section 2.6). The recirculation rate represents an average value based upon field thermal survey data.

2.6 HISTORICAL PLANT LOADS

2.6.1 Historical Summary of Net Generation

A complete hourly summary of historical net generation by unit and for total plant for April through August from 1973 through 1976 is included in Appendix 2.1A of O&R (1977). Because of day-night biological implications, the summary is segmented into daytime output (0600 to 2100 hours) and nighttime output (2100 to 0600 hours). This data summary is used in Subsection 2.6.2 to generate the representative diurnal generation profiles based on statistical analysis of the data. The following table summarizes the monthly capacity factors for the entire plant from April through August of 1973-1976:

Bowline Point Plant Capacity Factors (%)

	1973	1974	1975	1976
APR	69.8	14.0(a)	65.2	61.7
MAY	74.2	12.7(a)	33.7	62.7
JUN	66.5	27.7(a)	50.7	51.1(b)
JUL	63.9	47.9	66.1	47.1(b)
AUG	68.6	71.0	71.4	37.5(b)

(a) Startup of Unit 2 and scheduled outage of Unit 1 occurred during this period.

(b) Scheduled outages of Units 1 and 2 occurred during this period.

The data summary in O&R (1977) does consider three types of outages which result in zero generation on either unit or both units. A forced outage (designated by an "F" in the data summary) is an unanticipated trip or shutdown of a unit or of both units. A planned outage (designated by a "P") is an anticipated outage of a unit (never two units) for annual maintenance or overhaul that is scheduled several months in advance.

A scheduled outage (designated by an "S") is a semianticipated outage of a unit that is scheduled only a few days before shutdown, generally to perform necessary repairs or unanticipated maintenance.

Since forced and scheduled outages occur naturally during the day-to-day operations and cannot be specifically allocated to a generation schedule, they are included in the statistical analysis of this subsection as representative zero data. However, planned outages can be specifically allocated to a set time-period and frequency and therefore are not included as zero data in the statistical analysis.

Planned maintenance schedule dates are given in O&R (1977) for the future.

2.6.2 Representative Diurnal Generation Profile

The historical net generation data were analyzed to provide two basic descriptions of the daily generation cycle at the plant: representative diurnal generation profiles and cumulative distributions of plant capacity factors for each hour of the day.

The diurnal generation profiles are presented for each month from April through August in Appendix Tables 2.1B-1 through 2.1B-40 of O&R (1977). The daily cycles of plant capacity factor are representative of operating days on which the maximum and minimum hourly generating loads were at least 80 percent and 20 percent, respectively, of total plant generating capacity. The profiles show that the plant typically operates at minimum levels of 20 to 30 percent of capacity in the early morning hours, and reach maximum levels of 85 to 95 percent of capacity in mid-afternoon.

To establish typical monthly plant factors for daytime operation (0600 hours to 2100 hours) and for nighttime operation (2100 hours to 0600 hours), each month's data for 1975 and 1976 are averaged over the respective time periods, as presented in O&R (1977). The resulting day/night monthly plant capacity factors are summarized below:

	Representative Monthly Plant Capacity Factors (%)	
Month	Daytime (0600 hours to 2100 hours)	Nighttime (2100 hours to 0600 hours)
APR	81.2	52.9
MAY	79.9	59.6
JUN	80.8	61.8
JUL	84.3	71.1
AUG	78.1	61.7

The plant normally operates at less than 90 percent of capacity 30 to 60 percent of the time during peak load hours, but at less than 70 percent of capacity 80 to 90 percent of the time during hours of low generation.

3. RIVER PHYSICS AND CHEMISTRY

A complete description of river physics, topography, hydrodynamics, and chemistry is given in Chapter 3 of O&R (1977); the summary is presented here.

3.1 TOPOGRAPHY

The Bowline Point Generating Station is located at the upstream reach of the Haverstraw Bay area of the Hudson River; the area near the plant is typical of the wide, shallow area of Haverstraw Bay where the channel is on the west side of the river. The inlet to Bowline Pond, from which the plant draws its flow, was altered to permit greater exchange with the river; this alteration and plant operation has improved the water quality of the pond. Minor topographical changes were also made near the intake to facilitate the flow of water into and out of the plant. Other than these changes to the pond, the bottom topography of the river is relatively unaffected by plant operation.

3.2 RIVER HYDRODYNAMICS

The freshwater flows in the Lower Hudson River are determined mainly by runoff entering the river at Green Island. Because there are no gaging stations south of Green Island, the freshwater flow of the Lower Hudson is taken as the Green Island flow and corrected to account for tributaries that enter the river between Green Island and Wappingers Creek. The freshwater flow cycle follows a typical seasonal runoff pattern, with the highest flow during the spring and the lowest flows occurring during late summer/early fall; regulated releases from Sacandaga Reservoir are used to maintain the freshwater flow at Green Island at 3,000 cfs even during drought conditions. The long-term (1918-1975) annual average freshwater flow at Green Island is 13,268 cfs corresponding to a Lower Hudson River freshwater flow of 19,010 cfs.

Recent data have included the severe droughts of the early sixties and more recently the high-flow conditions of the early seventies. In the period 1971-1976 the rainfall has been above normal and has resulted in a number of record-setting freshwater flows.

The mean tidal flow in the Lower Hudson River varies from 425,000 cfs to zero at the Federal Dam in Troy. Near Bowline Point the average tidal flow is about 150,000 cfs; the average ebb current velocity is 1.44 fps and the average flood current velocity is 0.96 fps.

Net non-tidal flow refers to the circulation patterns that are related to the net velocity distribution, which is a result of dynamic interactions between the tidal currents and salinity distribution. The presence of freshwater flow in a system in which waters of different density are brought into contact with each other and vertical mixing generated by tide-induced turbulence control these distributions. Net non-tidal flow is important because it provides additional water for dilution of discharges. Its effect on dilution flow is weakest when salt is not present. The Bowline Point plant is located within the salt-intruded reach when the freshwater flow is below 26,000 cfs. This flow corresponds to a minimum dilution (plant flow/dilution flow) ratio of 1:22.4. However, using the long-term average condition, the ratio is about 1:25.8.

The operation of the Bowline Point plant has little effect on the freshwater or tidal flow in the Lower Hudson River; the maximum estimated consumptive use of water by the once-through cooling system of the Bowline Point station is 12 cfs or 0.07% of the average freshwater flow in the river. During recent periods of high freshwater flow, the net non-tidal flow near Bowline Point was probably lower, although it still significantly supplements the freshwater flows.

4. NEAR-FIELD THERMAL EFFECTS

4.1 RIVER AMBIENT TEMPERATURE

4.1.1 Introduction

Ambient temperatures of water in the Hudson River estuary vary significantly in space and time, due to local, seasonal, and random variations in the many factors influencing these temperatures. Excluding the general geographical setting and climatological conditions of the Hudson River basin, water temperatures in the estuary are affected primarily by the following factors:

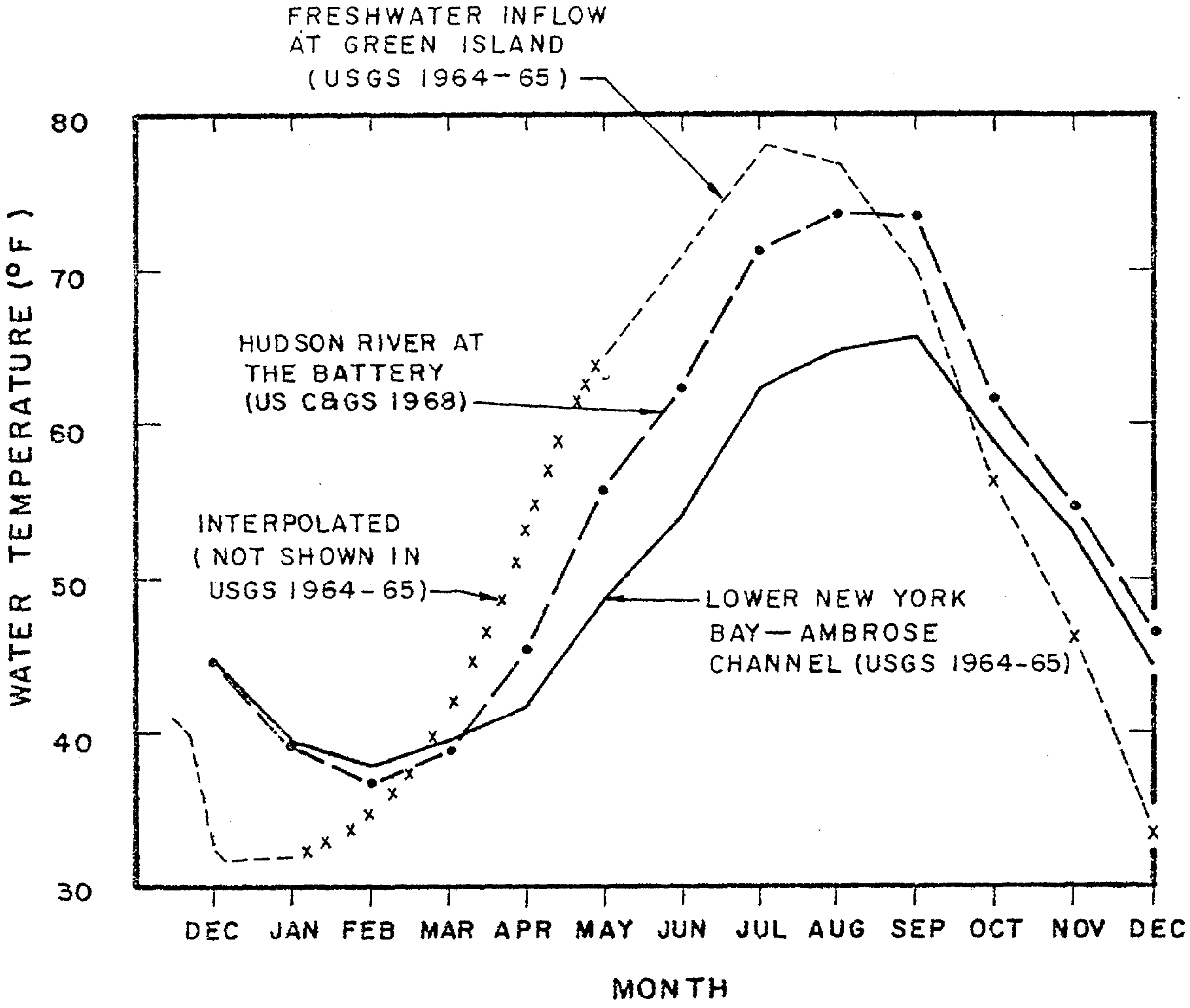
1. Temperature of the ocean water entering the estuary during the flood phase of the tidal cycle
2. Temperature and flow rate of freshwater entering the estuary
3. Heat exchange between the body of water and its surroundings.

The two background temperatures, i.e., those of the ocean water and freshwater entering the estuary, follow the general seasonal pattern of the northeastern portion of the United States, being lowest during January and February, and highest during July and August. The ocean water is generally warmer during the winter and cooler during the summer than entering freshwater, whose temperature rises and falls more rapidly than that of the ocean water during the spring and fall, respectively.

These trends can be observed in Figure 4-1, in which the 1964 monthly average temperatures of freshwater entering the estuary at Green Island (the head of the Hudson River estuary) are compared with monthly average temperatures of the ocean water entering the estuary at its mouth.

FIGURE 4-1

COMPARISON OF SEASONAL VARIATIONS IN TEMPERATURES OF THE OCEAN AND FRESH WATERS ENTERING THE HUDSON RIVER ESTUARY (CONDITIONS OF 1964)



4.1.2 Historical Data

The majority of available Hudson River temperature data were collected after 1966, although some earlier data are also available. A list of ambient river temperature measurements indicating (a) source of data, (b) locations of measurements, (c) year and month of each measurement, (d) number of measurements taken at a given location, and (e) mean and range of measured temperatures is presented in Part 4 of Appendix 4 of LMS 1975a (Volume 4).

Figures 4-2 through 4-5 present the mean and range of ambient water temperatures along the estuary for each month of a 12-month period. These were determined from available temperature data measured in the Hudson River from 1949 through 1972.

4.1.3 Recent Data (1971-1976)

Temperature data, measured in the river channel in conjunction with the monthly water quality sampling programs conducted over the years 1971-1976, are presented in Table 4-1. In addition to the monthly sampling program, temperature data were also collected during the biological sampling program (primarily from 1973 on) conducted in the Bowline Point vicinity. The frequency of temperature measurements depended upon the number and frequency of samplings for the specific biological sampling program, but it was generally measured at least once a week during the program's early years, increasing to two or three times a week more recently. Although temperatures were not generally taken directly in a thermal plume, these data do include any residual, far-field heat from Bowline Point or other generating stations which discharged into the river during the sampling period. Figures 4-6 through 4-13 present all the temperature

SUMMARY OF WATER QUALITY DATA OF THE LOWER HUDSON RIVER (1949-1972)

WATER TEMPERATURE (°F)

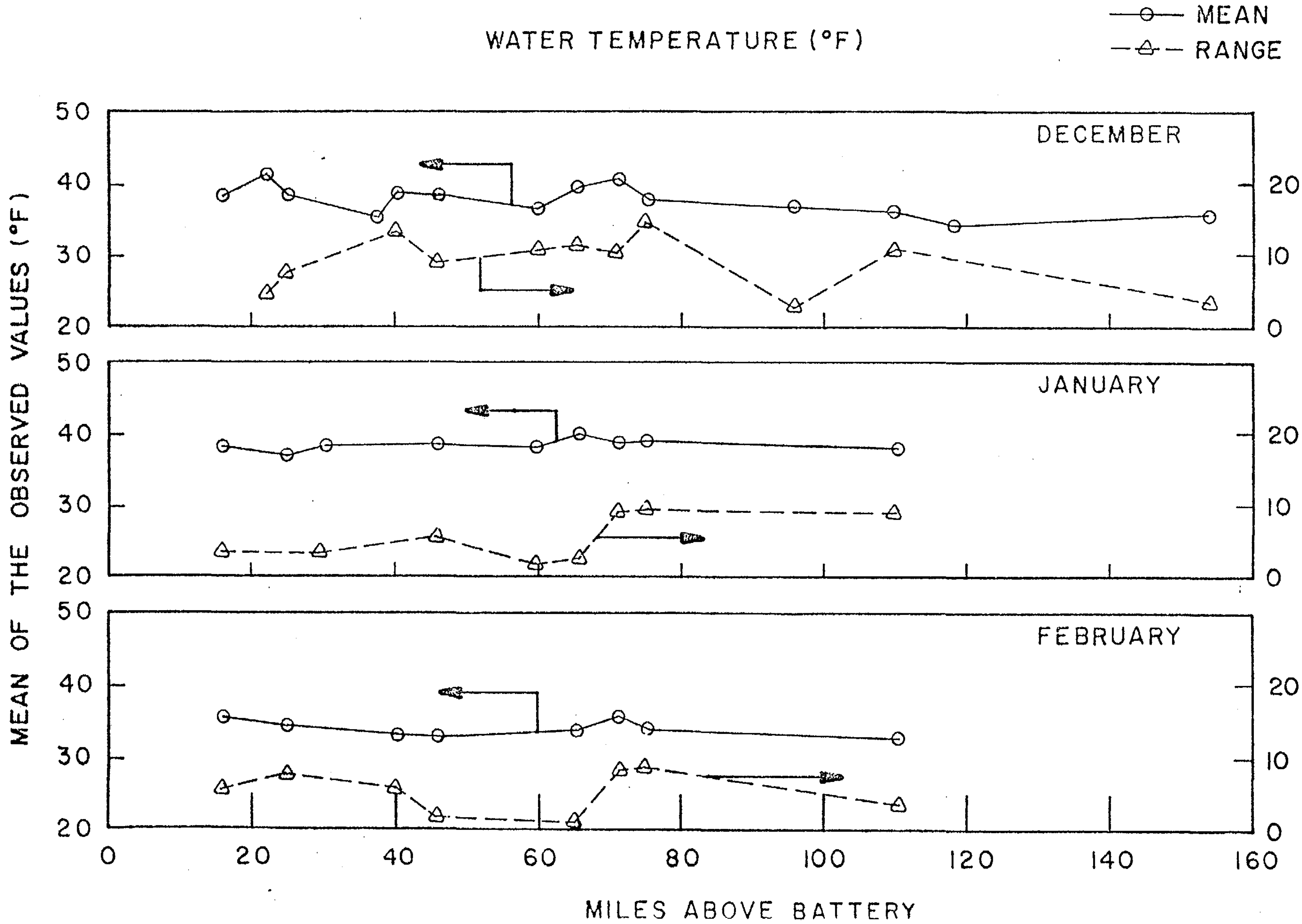


FIGURE 4-2

SUMMARY OF WATER QUALITY DATA OF THE LOWER HUDSON RIVER (1949-1972)

WATER TEMPERATURE (°F)

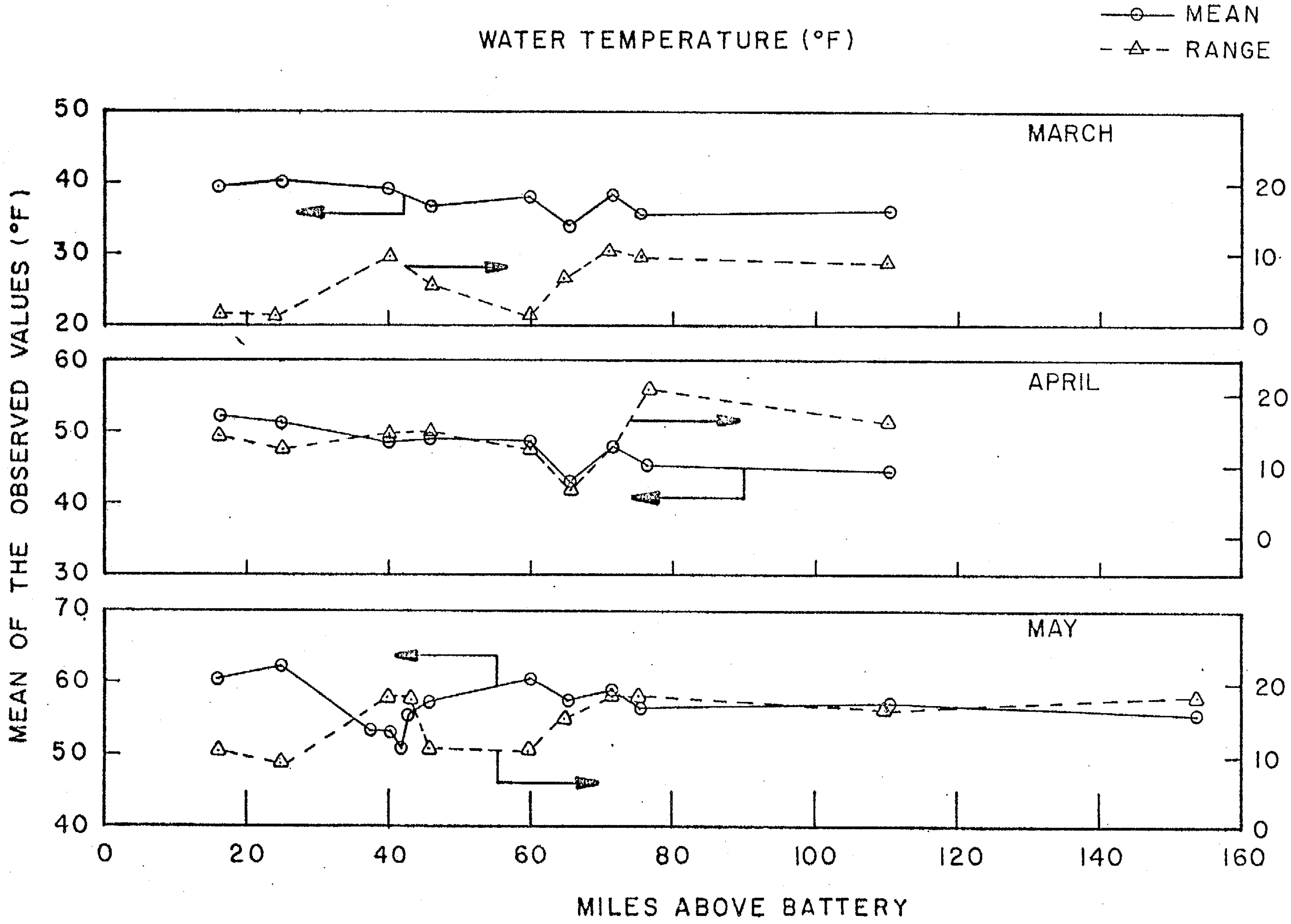


FIGURE 4-3

SUMMARY OF WATER QUALITY DATA OF THE LOWER HUDSON RIVER (1949-1972)

WATER TEMPERATURE (°F)

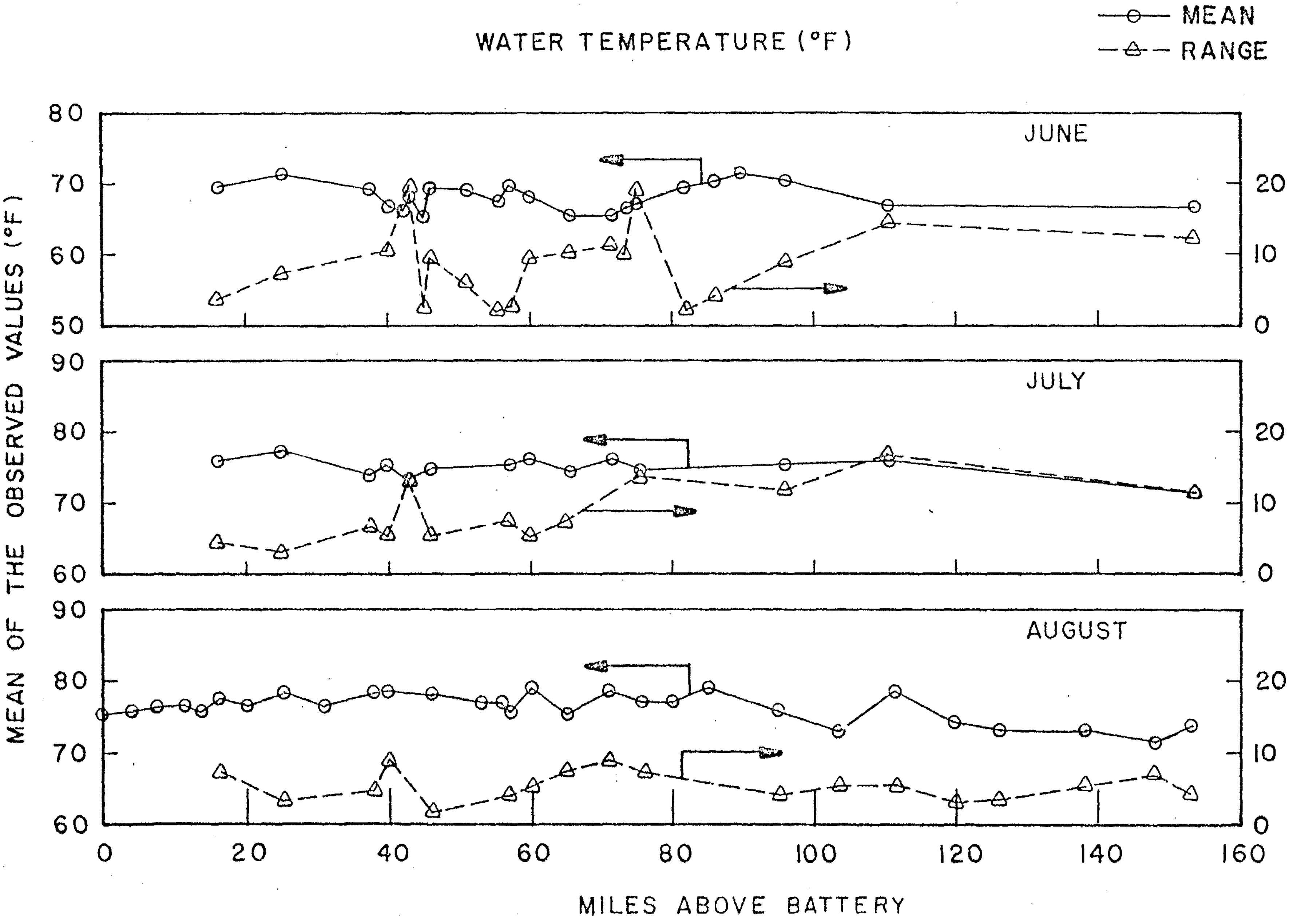


FIGURE 4-4

SUMMARY OF WATER QUALITY DATA OF THE LOWER HUDSON RIVER (1949-1972)

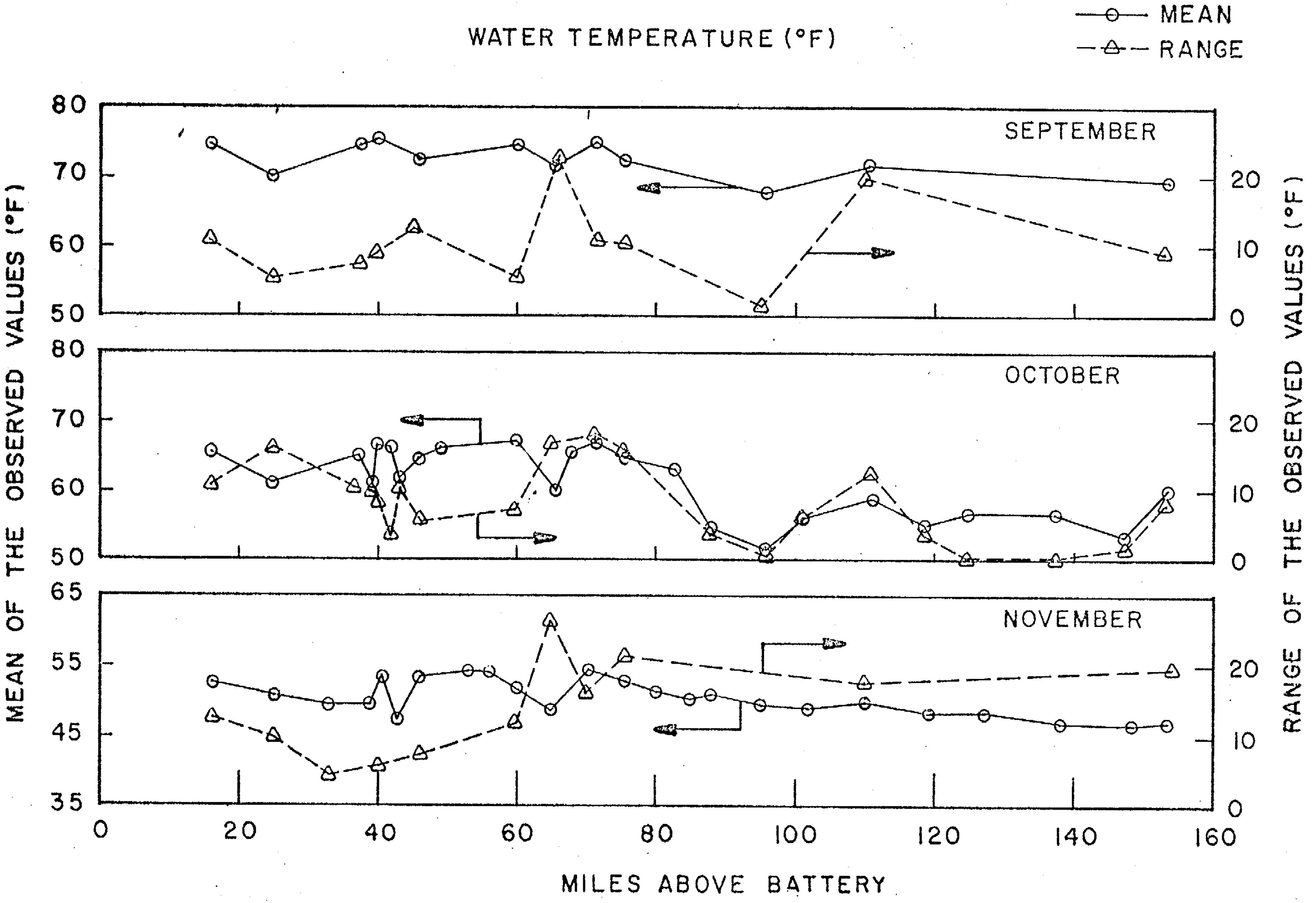


FIGURE 4-5

TABLE 4-1: AVERAGE MONTHLY WATER TEMPERATURES*
BOWLINE VICINITY - 1971-1976

I. WATER QUALITY VALUES

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	RANGE
1971	-	-	-	-	-	-	-	-	-	-	-	35.1	35.1
1972	-	-	-	-	53.5	-	71.7	79.4	70.7	-	-	-	53.0-79.4
1973	-	-	-	-	56.3	71.6	77.0	82.4	-	64.5	48.7	43.7	43.7-84.2
1974	36.0	32.8	39.6	67.4	62.1	70.7	76.7	78.6	67.4	54.3	51.4	36.5	32.5-79.7
1975	33.9	34.9	37.3	49.6	66.9	73.8	79.8	76.8	65.3	-	48.9	-	33.3-80.2
1976	-	34.7	40.4	47.8	58.4	67.3	78.0	76.8	70.3	61.1	45.1	38.4	34.4-78.0

II. SUMMARY BOWLINE POINT - LOVETT VICINITY CHANNEL TEMPERATURE

1973	-	32.0	37.0	-	53.7	71.4	76.9	80.4	75.8	65.4	52.5	42.5
1974	-	-	-	47.5	59.2	69.6	76.2	78.6	71.6	61.3	53.9	38.9
1975	36.3	34.3	37.8	44.4	61.6	72.9	78.7	78.8	70.2	61.9	52.4	39.3
1976	32.4	35.6	39.8	50.6	59.4	70.1	77.8	77.3	72.1	57.3	44.4	36.4

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*Degrees F

MEAN WATER TEMPERATURE IN BOWLINE POND*

BOWLINE VICINITY – 1973

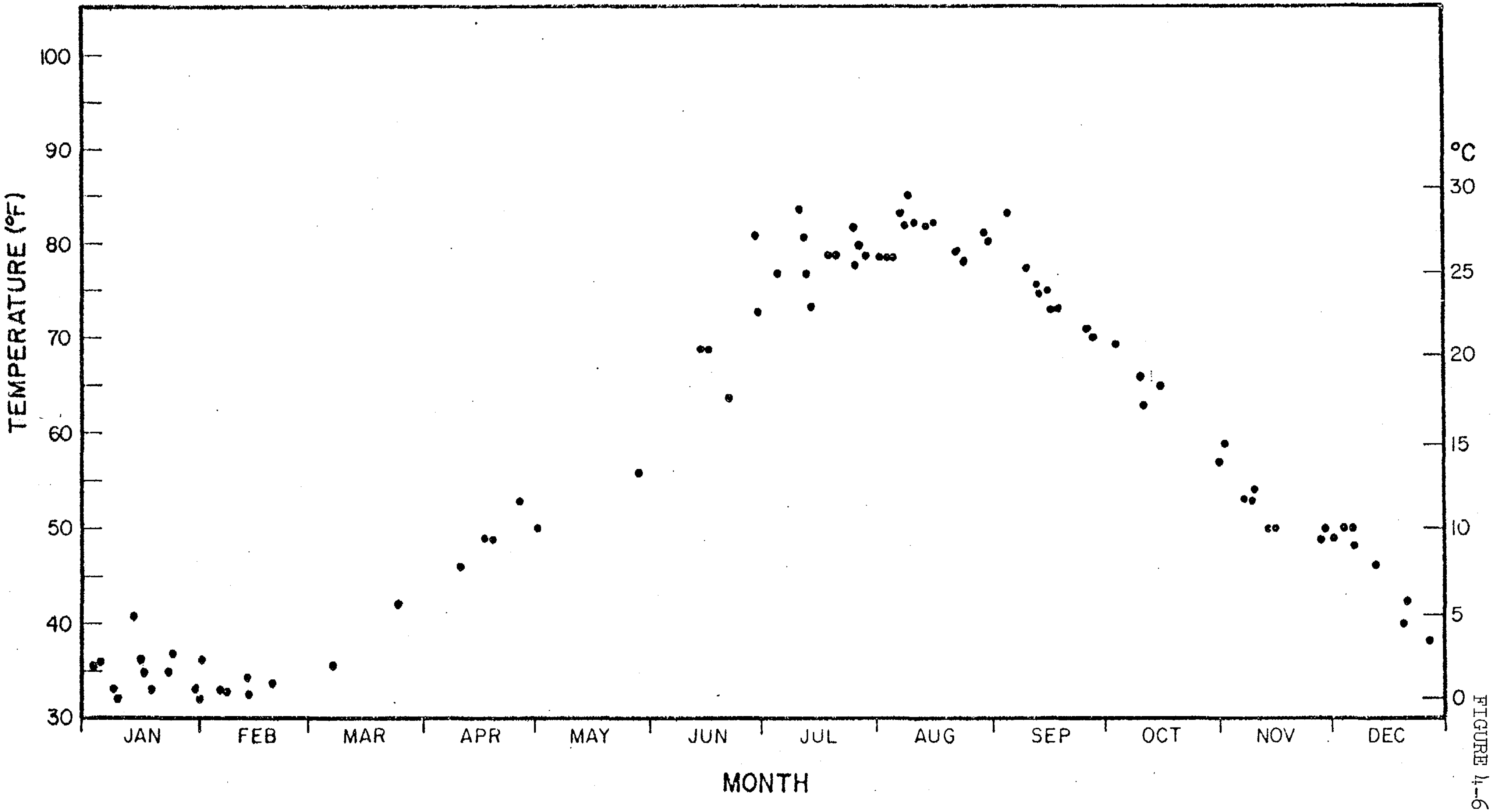


FIGURE 4-6

* Mean of surface, mid-depth and bottom.

MEAN WATER TEMPERATURE
IN BOWLINE POND*
BOWLINE VICINITY–1974

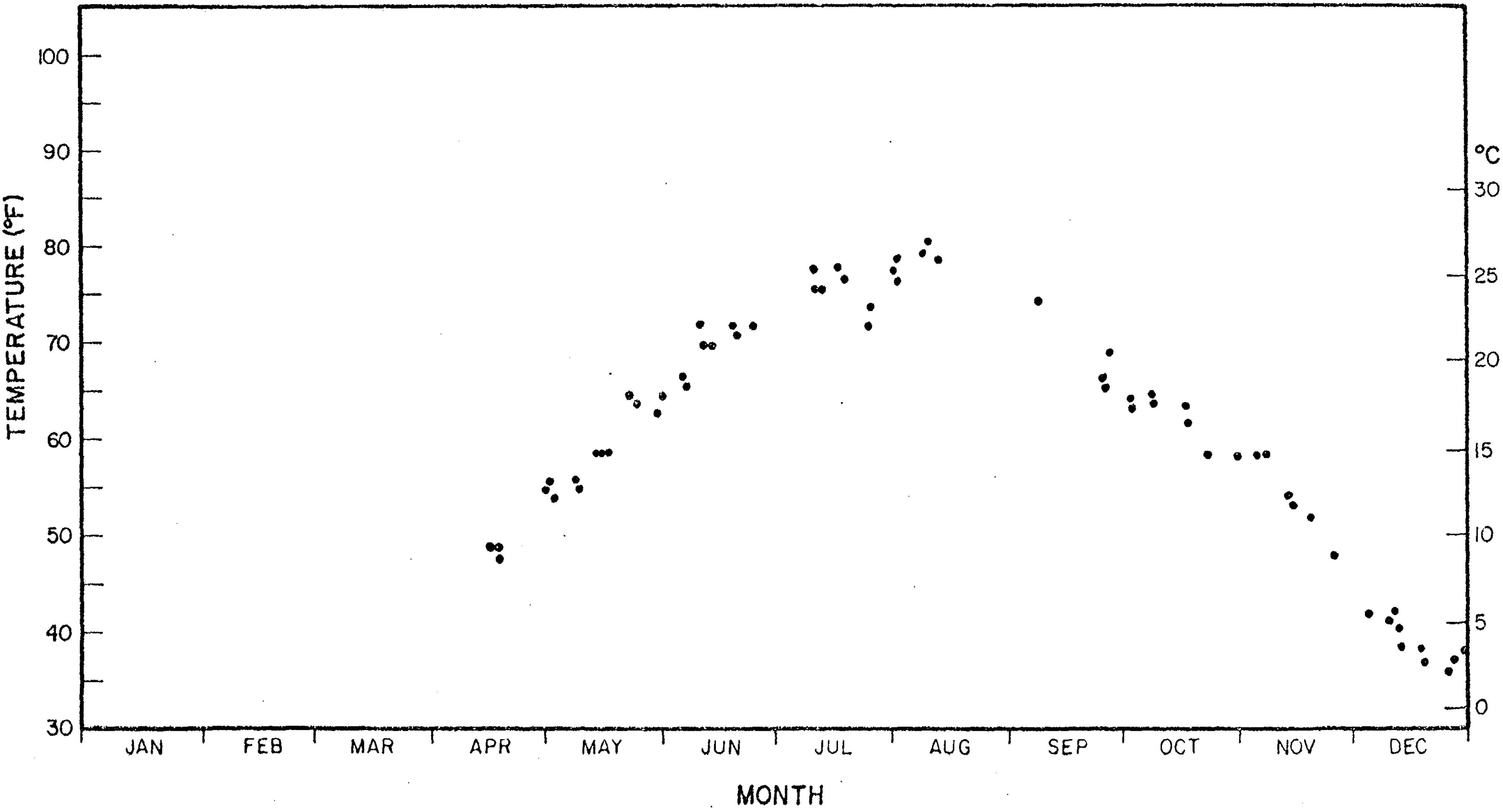


FIGURE 4-7

*Mean of surface, mid-depth and bottom.

MEAN WATER TEMPERATURE
IN BOWLINE POND*
BOWLINE VICINITY—1975

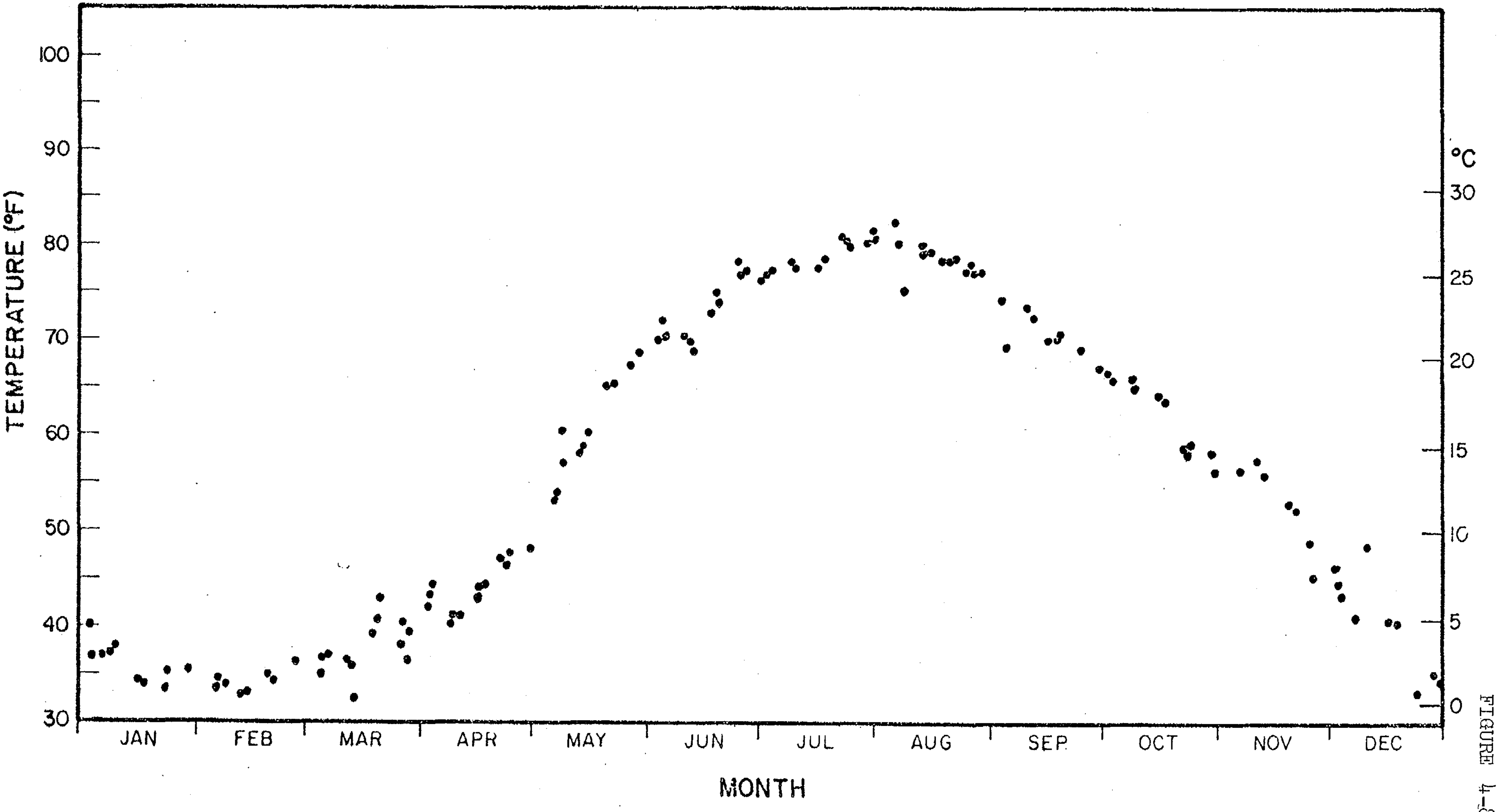
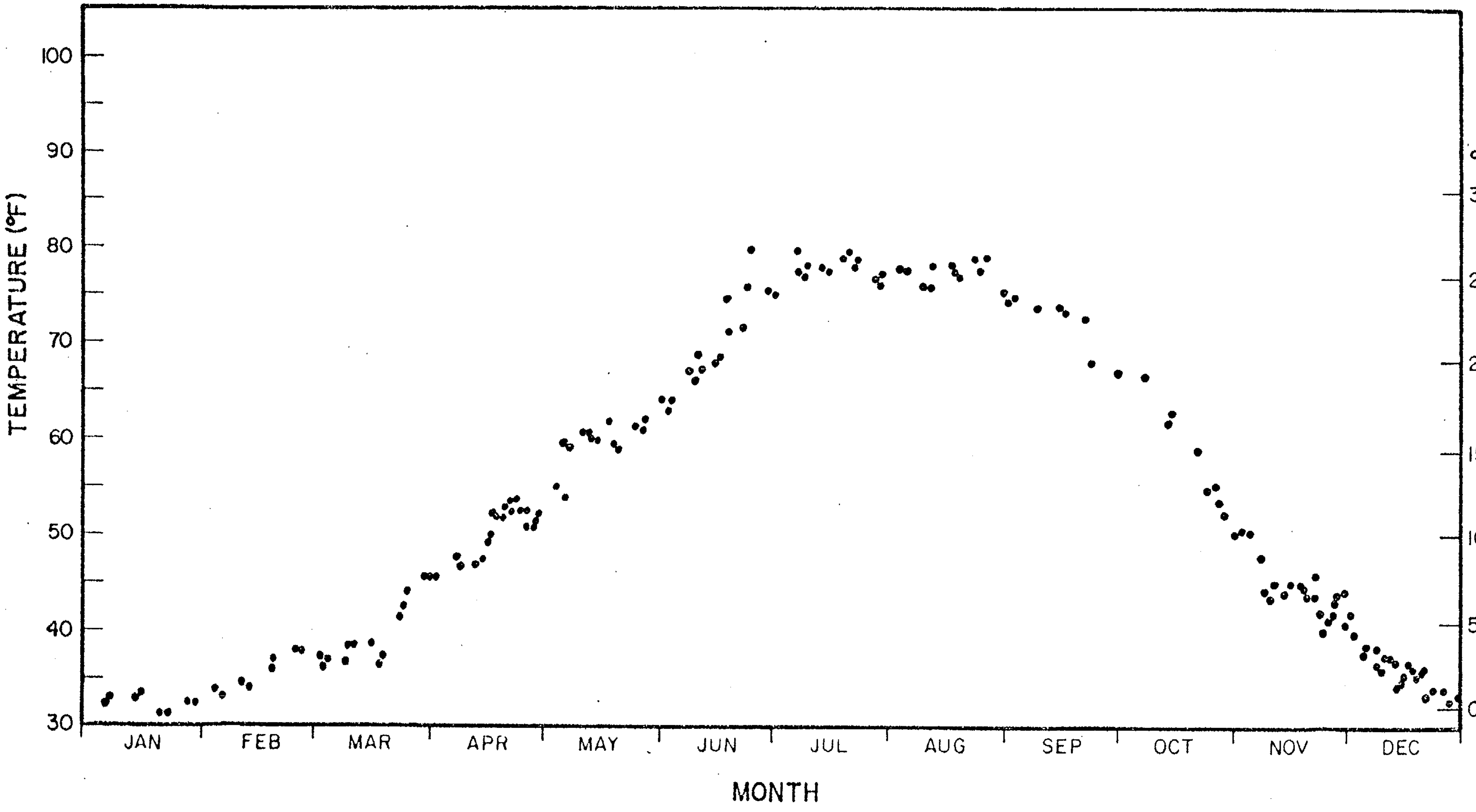


FIGURE 4-8

*Mean of surface, mid-depth and bottom.

MEAN WATER TEMPERATURE IN BOWLINE POND*

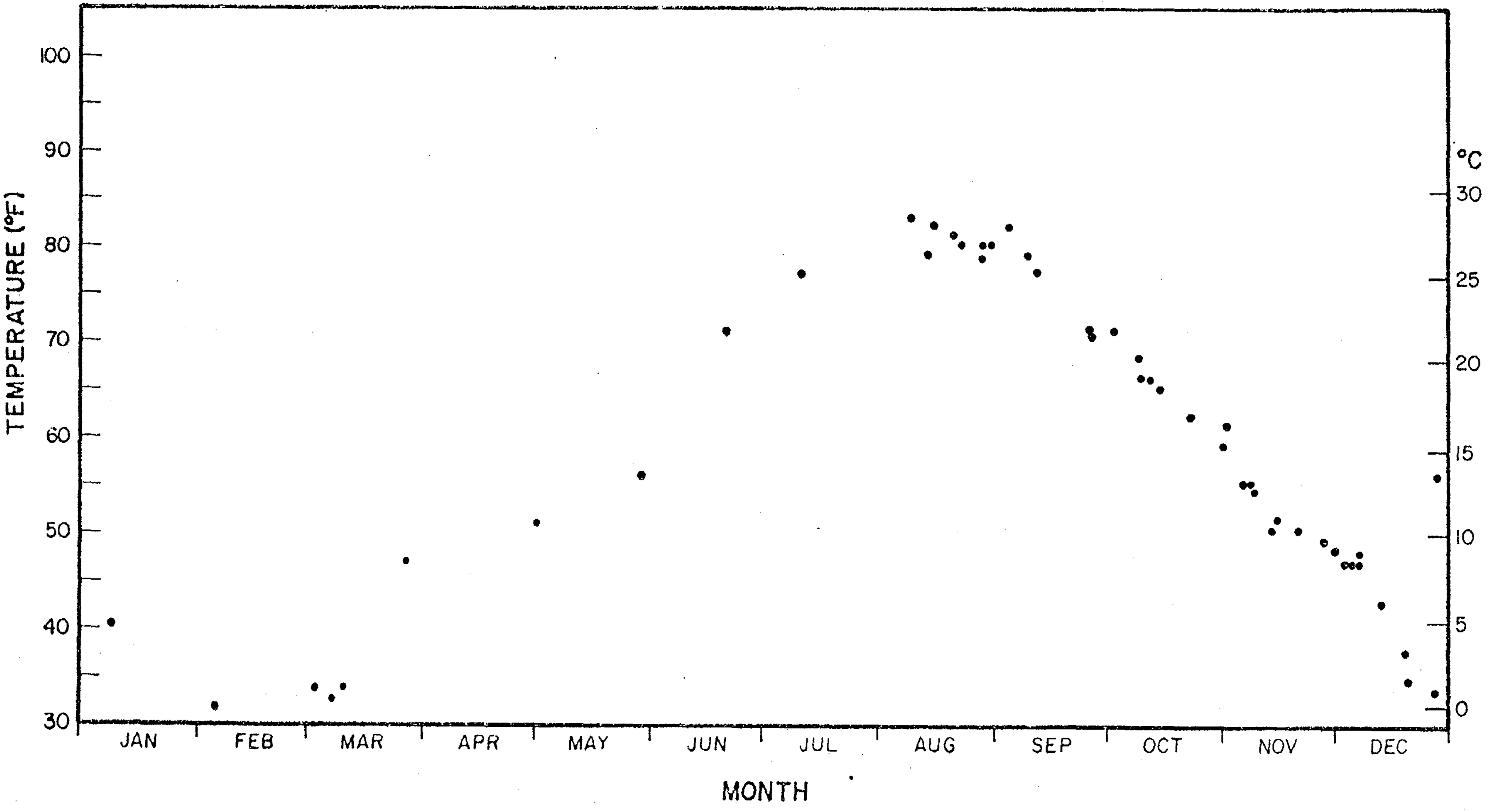
BOWLINE VICINITY – 1976



*Mean of surface, mid-depth and bottom.

FIGURE 4-9

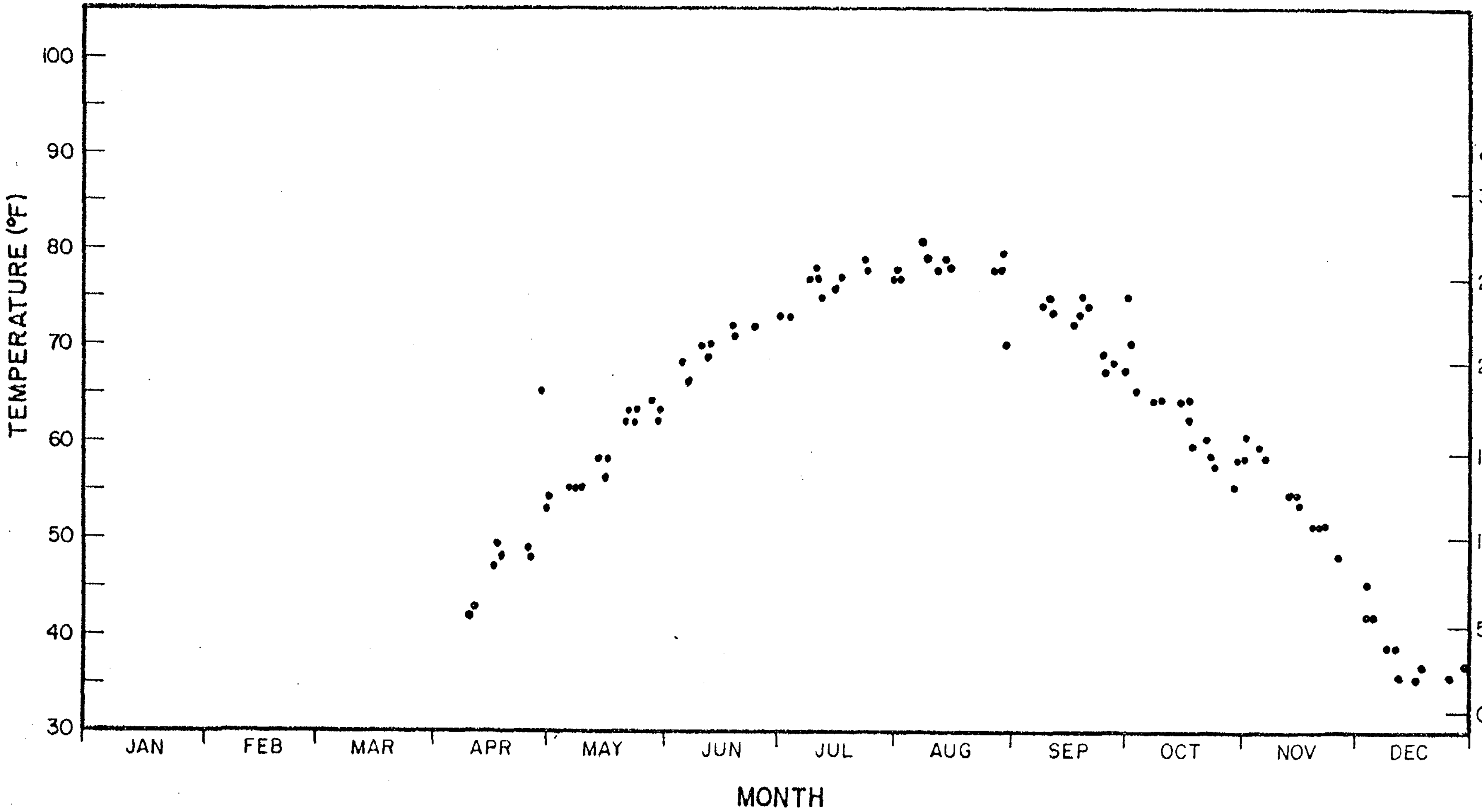
MEAN WATER TEMPERATURE*
BOWLINE VICINITY—1973



*Mean of surface, mid-depth and bottom.

FIGURE 4-10

MEAN WATER TEMPERATURE*
BOWLINE VICINITY—1974



*Mean of surface, mid-depth and bottom.

FIGURE 4-11

MEAN WATER TEMPERATURE*
BOWLINE VICINITY—1975

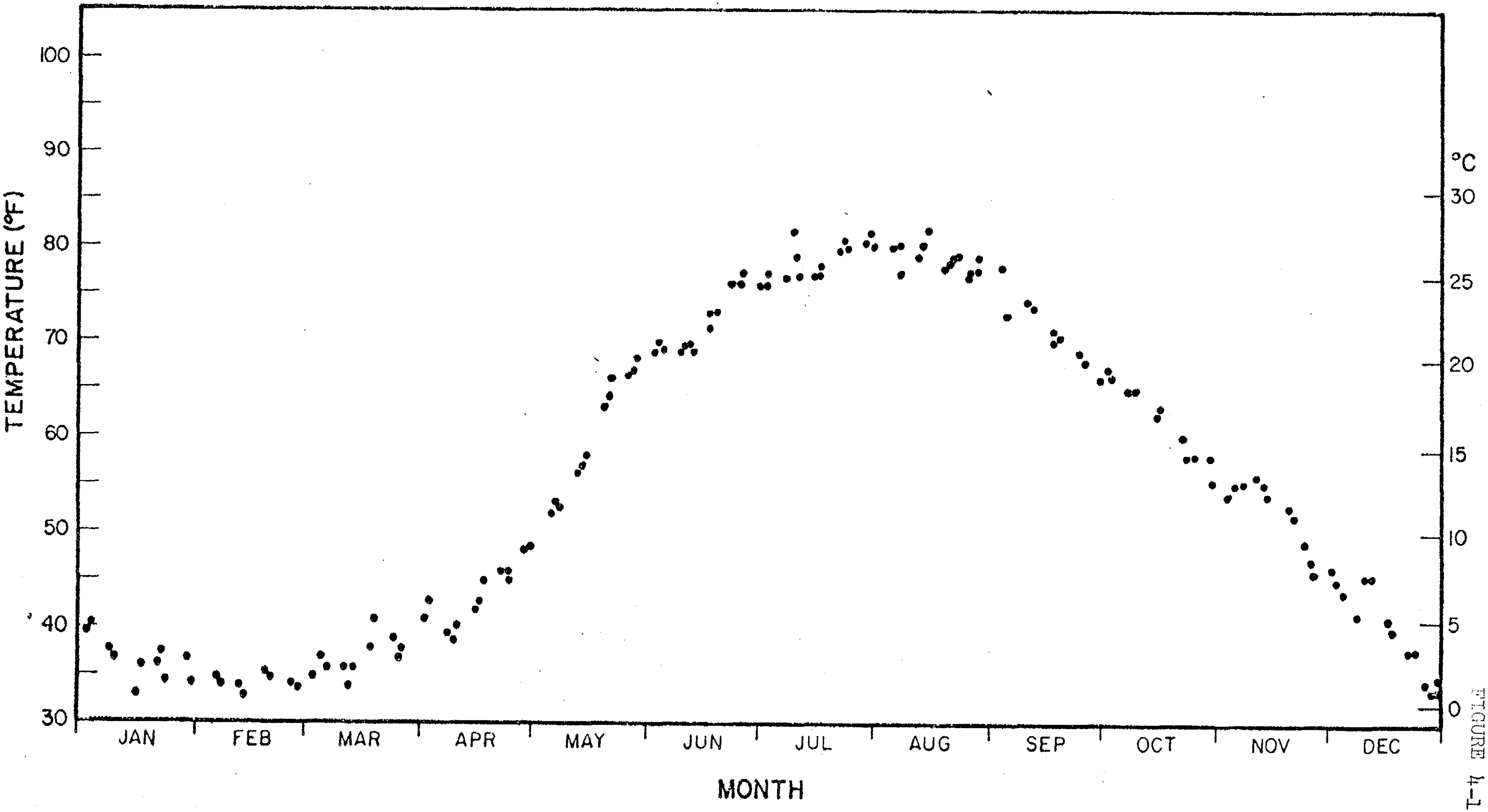


FIGURE 4-12

*Mean of surface, mid-depth and bottom.

MEAN WATER TEMPERATURE*
BOWLINE VICINITY-1976

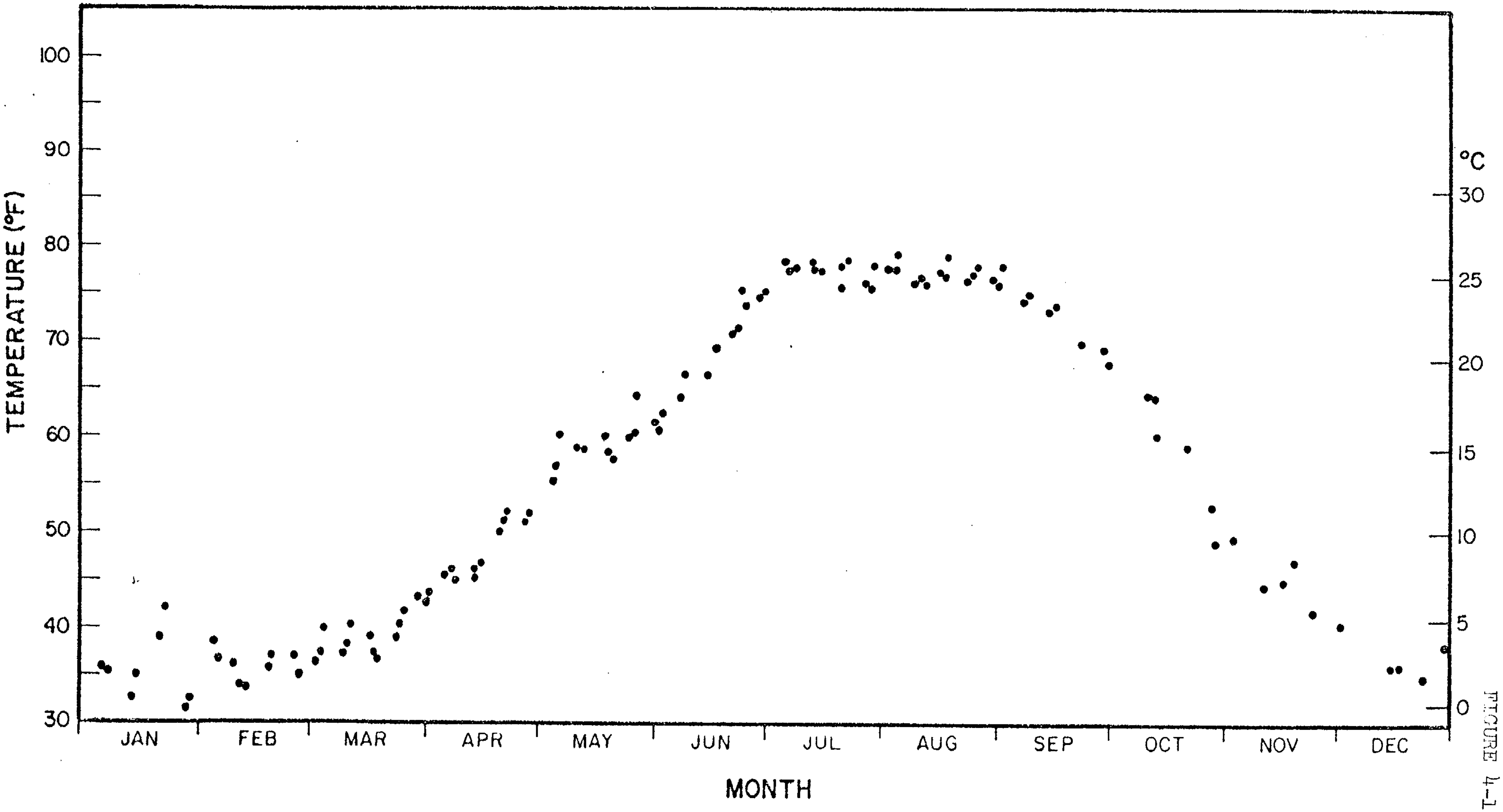


FIGURE 4-13

*Mean of surface, mid-depth and bottom.

data measured during the biological surveys in the pond and river, respectively, from 1973 through 1976. Each data point represents the mean of all depths for all biological stations in the pond and the river.

As can be seen in the figures, the data form a distinctly sinusoidal pattern with an average temperature of approximately 14 C (57.2 F) and an amplitude of about 12.7 C (22.9 F).

4.2 RESULTS OF BOWLINE POINT THERMAL SURVEYS

4.2.1 Summary of Surveys

This section of the report summarizes the results of the 14 thermal surveys which have been conducted at the Bowline Point Generating Station since the plant went into commercial operation in 1972 (Unit #1 went on line on 8 September 1972 and Unit #2 on 13 May 1974). The results of these surveys appear in earlier LMS reports (LMS 1974, 1975b, 1975c, 1975d, 1976a, 1976b).

The results of these surveys are summarized in Table 4-2, which shows the ambient surface temperature, maximum observed surface temperature rise, dilution ratio, and percent surface width and cross-sectional area bounded by the 4 F (2.2 C) temperature rise isotherm as functions of various plant parameters. The 4 F (2.2 C) temperature rise isotherm is used to represent the thermal plume because New York State thermal criteria require analyses of this isotherm and because it approximately represents the thermal plume as defined by U.S. EPA, 2 C (3.6 F).

As Table 4-2 illustrates, the surveys were performed under a wide range of plant operating conditions. For example, during the 14 surveys the cooling

TABLE 4-2: SUMMARY OF THERMAL SURVEYS
BOWLINE POINT GENERATING STATION & VICINITY
SEPTEMBER 1972 - OCTOBER 1975

SURVEY DATE	TIDAL PHASE	AMBIENT SURFACE TEMP. (°F)	MAXIMUM SURFACE TEMP. RISE ΔT_{sm} (°F)	DAILY AVERAGE PLANT TEMPERATURE RISE ΔT_o (°F)		DILUTION RATIO[a]		DAILY AVERAGE COOLING WATER FLOW RATE (10^3 GPM)		% SURFACE WIDTH BOUNDED BY THE TEMP. RISE ISOTHERM (≥4°F)	% CROSS-SECTIONAL BOUNDED BY TEMP. RISE ISOTHERM (≥4°F)	% OF TOTAL STATION LOAD (BASED ON GENERATION)
				UNIT 1	UNIT 2	UNIT 1	UNIT 2	UNIT 1	UNIT 2			
8 SEP 1972	FLOOD	75.0	3.4	12.0	NA	3.5	NA	316	NA	0.0	-	78.3
19 SEP 1972	HWS	74.0	3.1	10.5	NA	3.4	NA	384	NA	0.0	-	77.2
	EBB	74.0	3.5	-	NA	3.0	NA	-	NA	0.0	-	77.2
20 SEP 1972	EBB	71.0	3.6	11.5	NA	3.2	NA	316	NA	0.0	-	78.2
10 JAN 1973	FLOOD	32.5	5.5	13.0	NA	2.3	NA	384	NA	-	-	96.7
24 AUG 1973	LWS	79.0	2.9	8.5	NA	2.9	NA	316	NA	0.0	0.1	52.3
13 SEP 1973	FLOOD	75.5	4.6	12.2	NA	2.7	NA	384	NA	0.1	1.9	98.3
	HWS	75.5	4.3	12.2	NA	2.8	NA	384	NA	0.1	0.6	98.3
	EBB	75.0	3.3	12.2	NA	3.7	NA	384	NA	0.0	0.8	98.3
14 SEP 1973	LWS	75.5	3.7	11.9	NA	3.2	NA	384	NA	0.0	1.6	>99.0
	FLOOD	75.5	4.0	11.9	NA	3.0	NA	384	NA	0.0	1.0	>99.0
	HWS	75.0	2.9	11.9	NA	4.1	NA	384	NA	0.0	0.8	>99.0
2 AUG 1974	FLOOD	77.5	5.1	10.0	-	2.0	-	316	316	2.6	1.9	68.8
	HWS	78.0	4.2	10.0	-	2.4	-	316	316	0.3	0.5	78.7
	EBB	77.5	5.0	10.0	-	2.0	-	316	316	0.5	1.3	95.5
29 AUG 1974	EBB	79.5[b]	3.5	13.0	12.0	3.6		316	384	0.0	0.1	99.0
	LWS	79.5[b]	4.6	13.0	12.0	2.7		316	384	2.8	3.0	98.5
	FLOOD	79.0	5.7	13.0	12.0	2.2		316	384	4.9	2.8	98.7
	HWS	79.5	3.7	13.0	12.0	3.4		316	384	0.1	0.4	98.3
7 NOV 1974	EBB	57.0	4.4	7.0	10.0	1.9		316	316	0.6	0.7	75.8
	LWS	57.0	4.3	7.0	10.0	2.0		316	316	0.5	0.8	75.9
	FLOOD	57.0	5.4	7.0	10.0	1.6		316	316	2.1	0.7	76.0
	HWS	57.5	2.5	7.0	10.0	3.4		316	316	0.0	0.0	76.2
15 APR 1975	EBB	41.0	3.8	14.0	c	3.7	c	257	c	0.0	0.0	40.1
	LWS	41.0	6.5	15.0	c	2.3	c	257	c	4.1	2.8	40.5
	FLOOD	41.5	6.7	15.0	3.0	2.2	d	257	257	1.4	1.3	56.5
	HWS	42.0	3.3	15.0	c	4.6	c	257	c	0.0	0.6	40.7
18 JUN 1975	HWS	72.5	2.9	15.0	13.0	4.9		257	257	0.0	0.0	86.7
	EBB	73.0	2.6	15.0	0 - 3.0	5.8	d	257	0-257	0.0	0.0	50.7
	LWS	73.0	5.6	16.0	12.0	2.5		257	257	1.5	1.3	85.7
	FLOOD	73.5	7.2[b]	16.0	16.0	2.2		257	257	2.4	3.7	93.8
18 AUG 1975	FLOOD	78.5	5.9	15.0	14.5	2.5		316	316	2.9	2.0	93.3
	HWS	79.0	3.0	15.5	14.5	5.0		316	316	0.0	0.0	93.4
	EBB	79.0	3.4	15.5	14.5	4.5		316	316	0.0	0.0	92.9
	LWS	78.5	6.1	15.5	14.0	2.4		316	316	7.9[b]	5.5[b]	93.3
28 OCT 1975	HWS	57.0	2.4	14.0	c	5.6	c	316	c	0.0	0.0	35.4
	EBB	57.0	2.5	14.0	c	5.8	c	316	c	0.0	0.0	40.6
	LWS	57.0	5.4	17.0	c	3.5	c	316	c	0.9	0.9	47.3
	FLOOD	57.0	4.9	17.0	c	3.5	c	316	c	1.9	0.6	45.8

[a] Dilution ratio = Average plant temperature rise (°F)/maximum surface temperature rise (°F); unless otherwise specified (see d)

[b] Maximum tabled values

[c] Off line

[d] Dilution ratio calculated using the higher of the two ΔT_o's

NA - Not applicable since Unit 2 was under construction until 13 May 1974

- Not available

water flow ranged from 257,000 gpm (one unit on line) to 700,000 gpm (two units on line). Station load [based on generation (MW)] ranged from 35.4 to approximately 99% of capacity. The temperature rise through the plant ranged from 3.0 to 17.0 F[a] (1.7 to 9.4 C).

Surveys were also conducted over a wide range of ambient river temperatures, as shown in Table 4-2. These values ranged from 32.5[b] to 79.5 F (0.3 to 26.4 C). Maximum surface temperature rises ranged from 2.4 to 7.2 F (1.3 to 4.0 C) which, when combined with ambient river temperatures, yielded maximum surface temperatures ranging from 38.0 to 84.7 F (3.3 to 29.3 C).

The 10 January 1973 survey was not an elaborate thermal survey but was designed only to measure the possibility of a sinking plume existing during critical winter conditions. The results of this survey (Lawler 1972) indicated that there was no consistent tendency of the plume to sink toward the bottom even though the absence of vertical salt gradients and low ambient temperature was conducive to severe sinkage. Uniform temperatures, surface to bottom, were the more usual case during the survey and agreed with other studies (Pease 1976). Additional analyses performed for the Indian Point station (Lawler 1972) indicated that a sinking plume occurs very infrequently, if at all, because of salinity gradients, temperature, and density differences present in the river near Indian Point. Bowline Point is south of Indian Point and more affected by salinity which is a major deterrent to a sinking plume. Therefore, based on these studies (Lawler 1972; Pease 1976) and on the angle of the diffuser, it is

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[a] Data supplied by O&R.

[b] Before Unit #2 was in commercial operation.

expected that the Bowline Point plume will rarely sink and when certain conditions are present, will not sink but be neutrally buoyant, affecting as much of the bottom as the surface.

A comparison of the field results with the thermal criteria appears below.

4.2.2 Comparison of Field Results with New York State Thermal Criteria

The maximum percentages of surface width and cross-sectional area observed to be within the 4 F isotherm during the thermal surveys were 7.9 and 5.5%, respectively. Both maxima occurred on 18 August 1975 when the plant was operating at 93% capacity, based on net generation. Both these values are considerably less than the state thermal criteria of 67 and 50% for surface width and cross-sectional area, respectively, and based on these values no violations are expected to occur in the future at the Bowline Point Generating Station.

Figure 4-14 is a frequency plot of the maximum surface temperature rises (delta-T_{sm}) observed at Bowline Point. As this indicates, a delta-T_{sm} of 7.7 F (4.3 C)occurs less than 1% of the time. Based on this frequency of occurrence, in order for the 90 F maximum surface temperature criterion to be violated ($\geq$91 F [32.8 C])* the river <u>ambient</u> temperature must exceed 83.3 F (28.5 C), a temperature which has never been observed in the Bowline Point area. Therefore, no violation is expected since the frequency with which the combination of maximum ambient temperature and maximum surface temperature rise would be likely to occur is very small.

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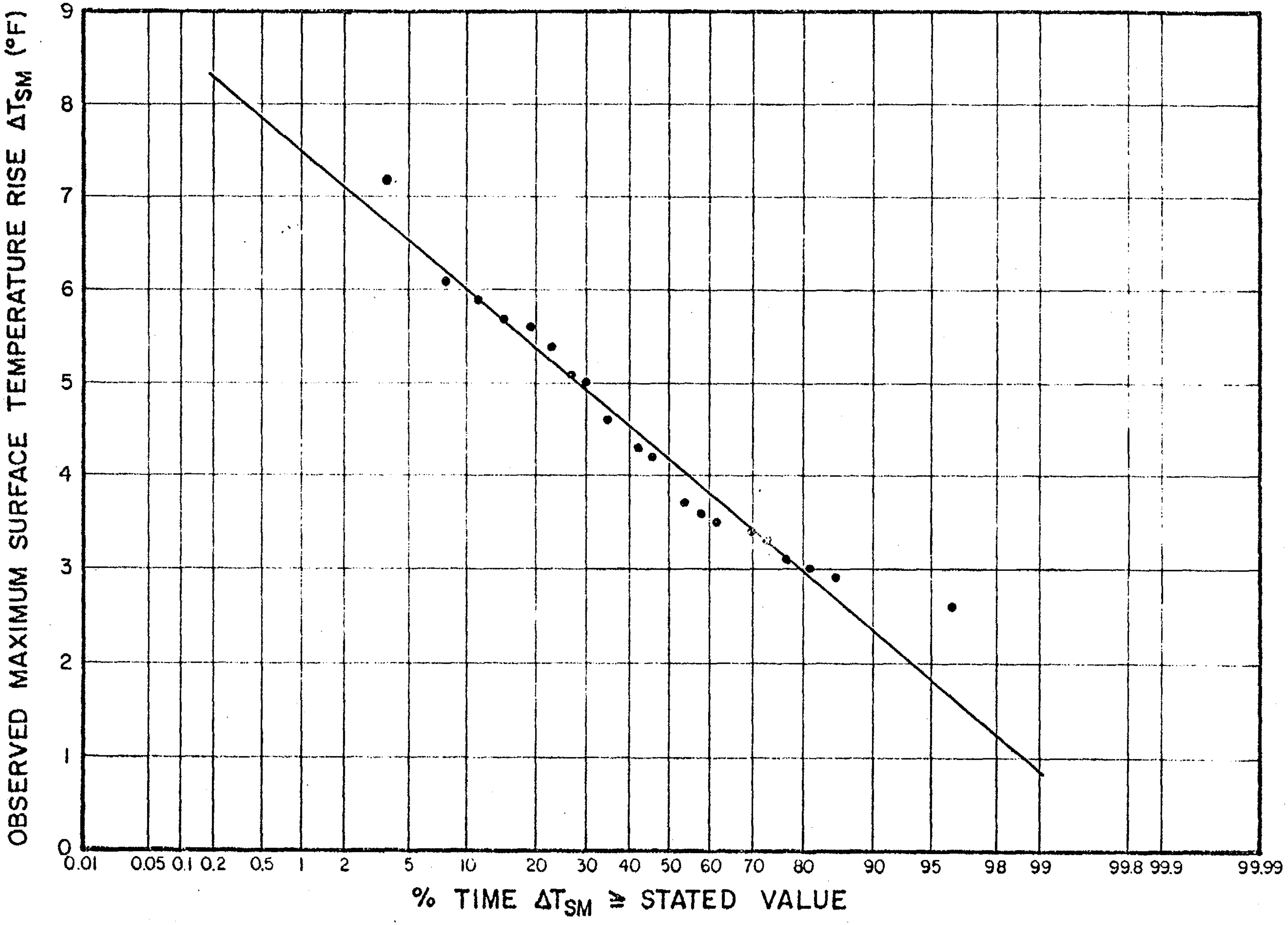
*The value 32.8 C refers to 91 F, the surface temperature which cannot be exceeded based on the 90 F criterion.



MAXIMUM SURFACE TEMPERATURE RISE
BOWLINE POINT GENERATING STATION AND VICINITY—1972-1975

FIGURE 4-14

4.2.3 Areal and Volumetric Dimensions of Discharge Plume

Surface isotherm maps and cross-sectional temperature profiles for selected surveys conducted after May 1974 (after Unit 2 went on line) are presented in the Appendix. The surveys were chosen as being representative of fall (11 November 1974), spring (15 April 1975), late spring/early summer (18 June 1975) and summer (18 August 1975) seasons[a]. The chosen surveys represent the worst case for each season, i.e., the survey which indicated the largest plume area and/or warmest temperatures. Table 4-3 summarizes the areal and volumetric dimensions of the 4 F (2.2 C) (and bounding) temperature rise isotherms for the survey dates mentioned above. The table also presents the percentage of volume and surface area of the various isotherms for one upstream and one downstream tidal excursion. The maximum surface area of a 4 F (2.2 C) isotherm occurred on 18 June 1975 and was 50.5 acres. As might be expected, the maximum volume of the 4 F (2.2 C) isotherm also occurred on this date and was 170 acre-ft. Because of the large surface area and volume of the river in the vicinity of the plant (the distance covered by two tidal excursions), the ratios of the 4 F (2.2 C) isotherm areas and volumes to river areas and volumes are very small (see Table 4-4).

For purposes of calculating the effects of the thermal plume, the maximum areal and volumetric extent of the Bowline Point thermal plume is taken from the 18 June or 18 August 1975 surveys. These surveys represent the plume under normal high capacity operation (93%) and at its largest dimensions for two critical pumping rates during summer conditions. The lower pumping rates should decrease the efficiency of the diffuser and the increased buoyancy

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[a] No winter surveys were conducted after both units went on line. When more than one survey was conducted during any season, the survey which showed the largest thermal influence was chosen.

TABLE 4-3: SUMMARY OF VOLUME AND SURFACE AREA OF THE THERMAL PLUME WITH RESPECT TO THE 4°F AND BOUNDING TEMPERATURE RISE ISOTHERMS BOWLINE POINT GENERATING STATION AND VICINITY - 1974-1975

DATE	TIDAL PHASE	TEMPERATURE RISE ISOTHERM (>) °F	HEAT LOAD (BBtu/DAY) UNIT 1	HEAT LOAD (BBtu/DAY) UNIT 2	SURFACE AREA (ACRES)	PERCENT SURFACE AREA[a]	VOLUME (ACRE-FT)	PERCENT VOLUME[a]	PERCENT CAPACITY
7 NOV 1974	EBB	3	26.5	48.0	0.83	0.012	3.56	0.002	75.8
		4			0.14	0.002	1.72	0.001	
		5			b	0.006	b	0.000	
	LWS	3	26.5	48.1	3.44	0.050	25.80	0.018	75.9
		4			0.16	0.002	0.41	0.001	
		5			b	0.000	b	0.000	
	FLOOD	3	26.5	48.2	11.50	0.163	36.70	0.025	76.0
		4			1.15	0.016	9.76	0.007	
		5			1.15	0.016	2.87	0.002	
	HWS	3	26.5	48.2	b	0.000	b	0.000	76.2
		4			b	0.000	b	0.000	
		5			b	0.000	b	0.000	
15 APR 1975	EBB	3	39.4	0.0	8.27	0.117	26.60	0.018	40.1
		4			b	0.000	b	0.000	
		5			b	0.000	b	0.000	
	LWS	3	39.8	0.0	3.67	0.052	41.30	0.028	40.5
		4			1.84	0.026	6.43	0.004	
		5			0.92	0.013	4.13	0.003	
		6			0.92	0.013	3.21	0.002	
	FLOOD	3	40.1	15.4	7.58	0.107	111.00	0.076	56.5
		4			1.84	0.026	32.10	0.022	
		5			0.46	0.016	6.43	0.004	
		6			0.12	0.002	4.36	0.003	
		7			0.12	0.002	0.92	<0.001	40.7
	HWS	3	40.0	0.0	5.74	0.080	51.20	0.035	
		4			b	0.000	b	0.000	
		5			b	0.000	b	0.000	
18 JUN 1975	HWS	3	42.7	42.5	0.01	0.000	4.59	0.003	86.7
		4			b	0.000	b	0.000	
		5			b	0.000	b	0.000	
	EBB	3	45.7	<3.8	b	0.000	b	0.000	50.7
		4			b	0.000	b	0.000	
		5			b	0.000	b	0.000	
	LWS	3	45.9	38.3	21.60	0.305	86.10	0.059	85.7
		4			0.92	0.013	9.20	0.006	
		5			0.18	0.002	3.10	0.002	
	FLOOD	3	46.3	45.5	141.00	1.995	604.00	0.410	93.8
		4			50.50	0.714	170.00	0.116	
		5			7.35	0.104	26.40	0.018	
		6			0.55	0.007	1.38	0.001	
18 AUG 1975	FLOOD	3	45.5	46.2	12.96	0.182	82.70	0.056	93.3
		4			7.35	0.104	75.80	0.052	
		5			1.38	0.020	12.60	0.009	
	HWS	3	46.0	45.8	0.69	0.010	1.84	0.001	93.4
		4			b	0.000	b	0.000	
		5			b	0.000	b	0.000	
	EBB	3	45.8	45.5	11.00	0.155	59.70	0.041	92.9
		4			b	b	b	0.000	
		5			b	b	b	0.000	
	LWS	3	46.3	45.5	29.40	0.415	321.00	0.281	93.3
		4			10.10	0.143	113.00	0.077	
		5			3.67	0.052	32.10	0.022	
		6			0.69	0.010	2.99	0.022	

[a] Two tidal excursions (ebb and flood); surface area = 7067 acres, volume = 146,987 acre-ft, see Table 4-4.

[b] No heat at the specified temperature rise

TABLE 4-4: COMPARISON OF SURFACE AREA AND VOLUME OF THE >4 F TEMPERATURE RISE ISOTHERMS WITH THE SURFACE AREA AND VOLUME FOR TWO TIDAL EXCURSIONS BOWLINE POINT GENERATING STATION

VALUES	SURFACE AREA OF ≥4 F TEMPERATURE RISE (ACRES)	RATIO OF AFFECTED AREA[a]	VOLUME OF ≥4 F TEMPERATURE RISE (ACRE-FT)	RATIO OF AFFECTED VOLUME[a]
AVERAGE[b]	4.63	1:1528	26.2	1:5620
MAXIMUM	50.5	1:140	170.0	1:865

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[a] Based on two tidal excursions - one upstream (1.9 mi), and one downstream (3.6 mi): Volume - 146,987 acre-ft; surface area - 7067 acres (QLM 1971). Only 1975 and 1976 survey data used to calculated tidal excursions (LMS 1975b,c; 1976a).

[b] Average of 7 Nov 1974, 15 Apr 1975, 18 Jun 1975, 18 Aug 1975; plant capacity ranged from 40 to 94%.

of the heated effluent during summer conditions also add to enlarging the plume. In addition, the winter plume is reduced by the decrease in total heat rejected to the river (Section 2.5); therefore these surveys are a conservative representation of the plume throughout the year.

4.2.4 Frequency Distribution of Discharge Plume

One definition of a zone of discharge is given in the U.S. EPA 316(a) technical guidance manual dated 30 September 1974 as:

> "...that portion of the receiving waters which is within the delta 2 C isotherm of the plume 30% or more of the time...."

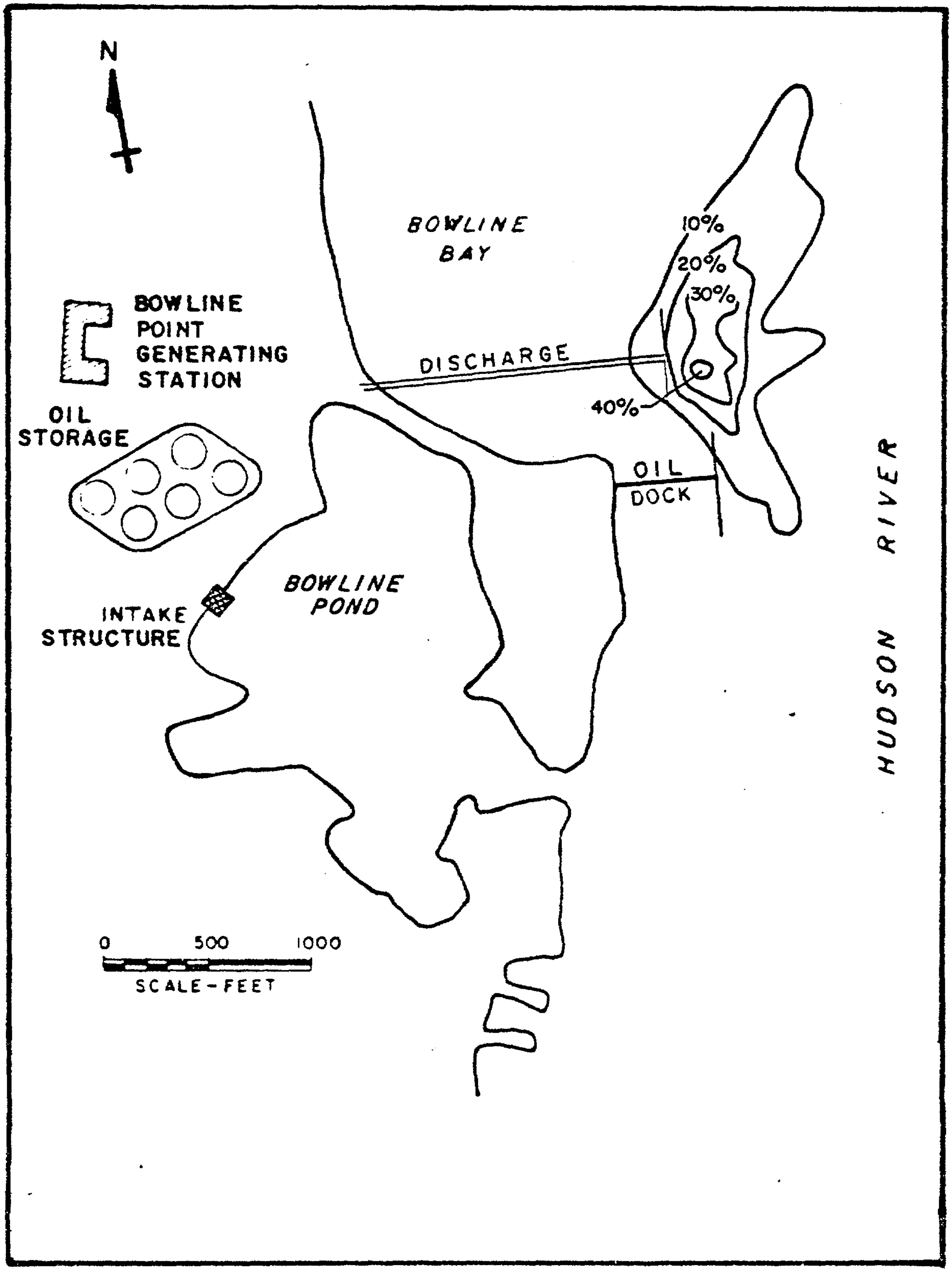
The results of five thermal surveys (representing a total of 19 surface temperature rise isotherm mappings) were used to determine the required zone of discharge; all of these represented cases where station loads (based on average daily generation) were 50% or more of the maximum station capacity (1200 MW, net). Four of the 19 isothermal maps showed surface temperature rises of less than 2 C (3.6 F). The five survey dates used were: 2 and 29-30 August, 7 November 1974; 18 June and 18 August 1975 (see Table 4-2 for plant operating conditions). The contours drawn in Figure 4-15 represent the portion of the receiving water body that falls within the 2 C (3.6 F) temperature rise isotherm 10, 20, 30, and 40% of the time. Similar analyses for the 3 C (5.4 F) and 4 C (7.2 F) isotherms were not significant because of the infrequent occurrence of these isotherms at Bowline Point.

4.3 VELOCITY-TEMPERATURE DISTRIBUTION - IMMEDIATE NEAR-FIELD

Field data and hydraulic and mathematical models are capable of representing the near-field and far-field temperature distributions resulting from a thermal

FIGURE 4-15

ZONE OF DISCHARGE
BOWLINE POINT GENERATING STATION AND VICINITY
2°C ISOTHERM



discharge. The major sources of these near-field patterns are theoretical, mathematical models based on conservation of mass and momentum. Before startup of the Bowline Point station, a model of this type (Single Submerged-Jet Model; see Section 4.4 and QLM 1969, 1971) was used to calculate the dilution ratios and velocity patterns from the Bowline Point submerged discharge under flood, ebb and slack tidal conditions. These results are reproduced in Figures 4-16, 4-17, and 4-18.

Recent field data (see Section 4.2) suggest that the theoretical dilutions from the submerged jet model are in excess of what was measured. Based on 14 thermal surveys, the dilutions (maximum initial temperature/surface temperature rise) were as follows:

	DILUTION	
TIDE	RANGE	AVERAGE
Flood	1.6-3.5	2.52
Ebb	1.9-5.8	3.46
Slack	2.0-5.6	3.39

In addition, field studies did not report the typical temperature patterns predicted by the model, i.e., continually decreasing temperature/velocities from a maximum at the port; instead the maximum temperature is uniform throughout the measured water column. The field studies indicate that the submerged diffuser provides very good initial mixing; within the first 20-40 ft from the diffuser, the discharge has reached dilution ratios of 2-6. However, after the initial dilution, the discharge does not appear to entrain any new ambient water and is diluted little before reaching the river surface. Studies (Robideau 1972) indicate that for a discharge such as the Bowline Point discharge, there may be a limit on the amount of dilution water available. Although Robideau's data did not cover the lower range, this information did suggest

SUBMERGED DISCHARGE DURING SLACK

BOWLINE POINT GENERATING STATION

RIVER VELOCITY = 0.02 FPS

℄ DEPTH OF SUBMERGENCE = 15.4 FT.

∡ X = 5°

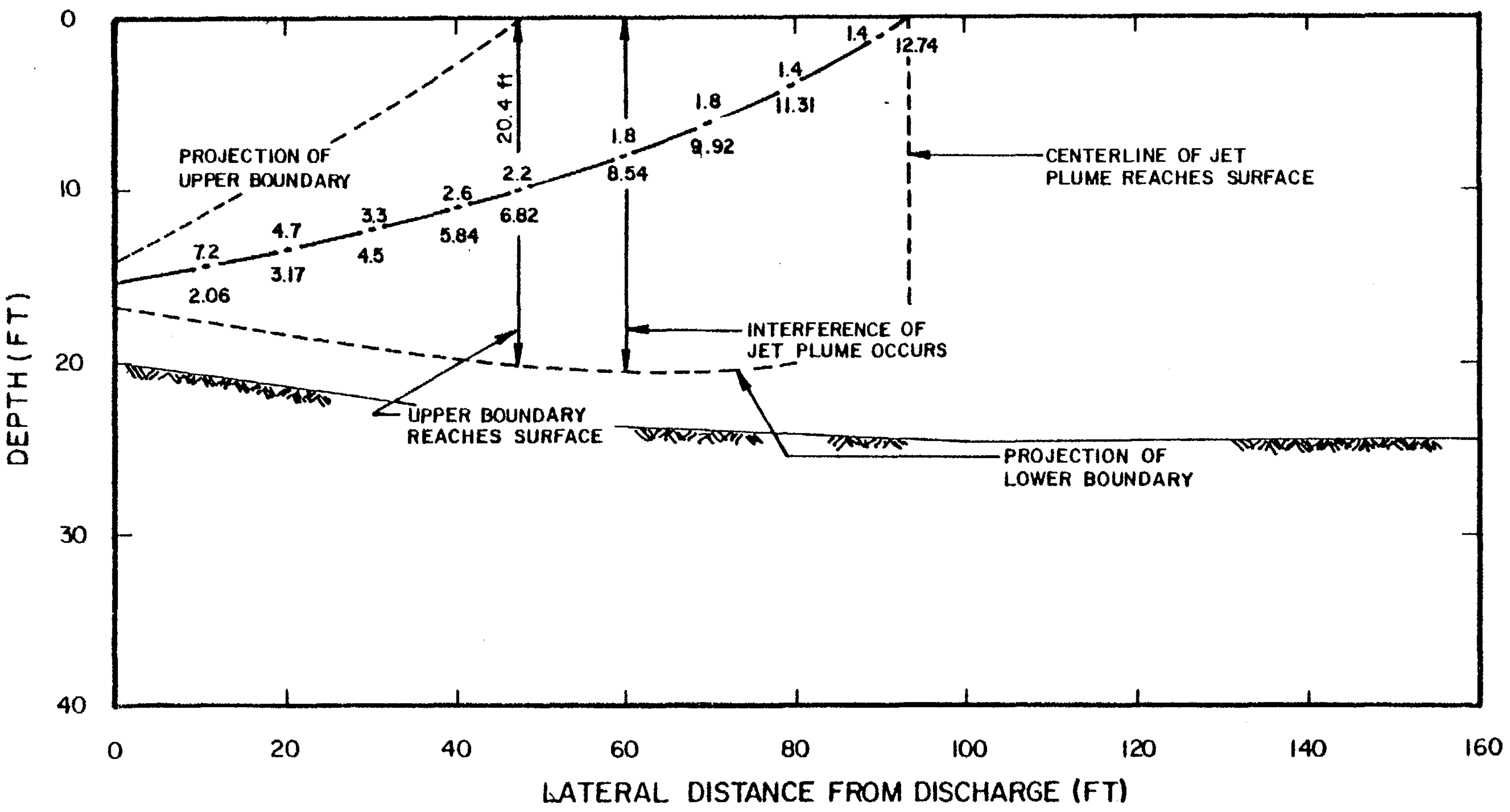
AMBIENT TEMPERATURE = 79°F

DISCHARGE TEMPERATURE = 94°F

2.4 = JET VELOCITY (fps)

– – – = CENTERLINE

3.57 = DILUTION RATIO



FIGURE

SUBMERGED DISCHARGE DURING EBB

BOWLINE POINT GENERATING STATION

RIVER VELOCITY = 2.20 FPS

℄ DEPTH OF SUBMERGENCE = 13.5 FT

∡ X = 5°

AMBIENT TEMPERATURE = 79°F

DISCHARGE TEMPERATURE = 94°F

2.4 = JET VELOCITY (fps)

— - — = CENTERLINE

3.57 = DILUTION RATIO

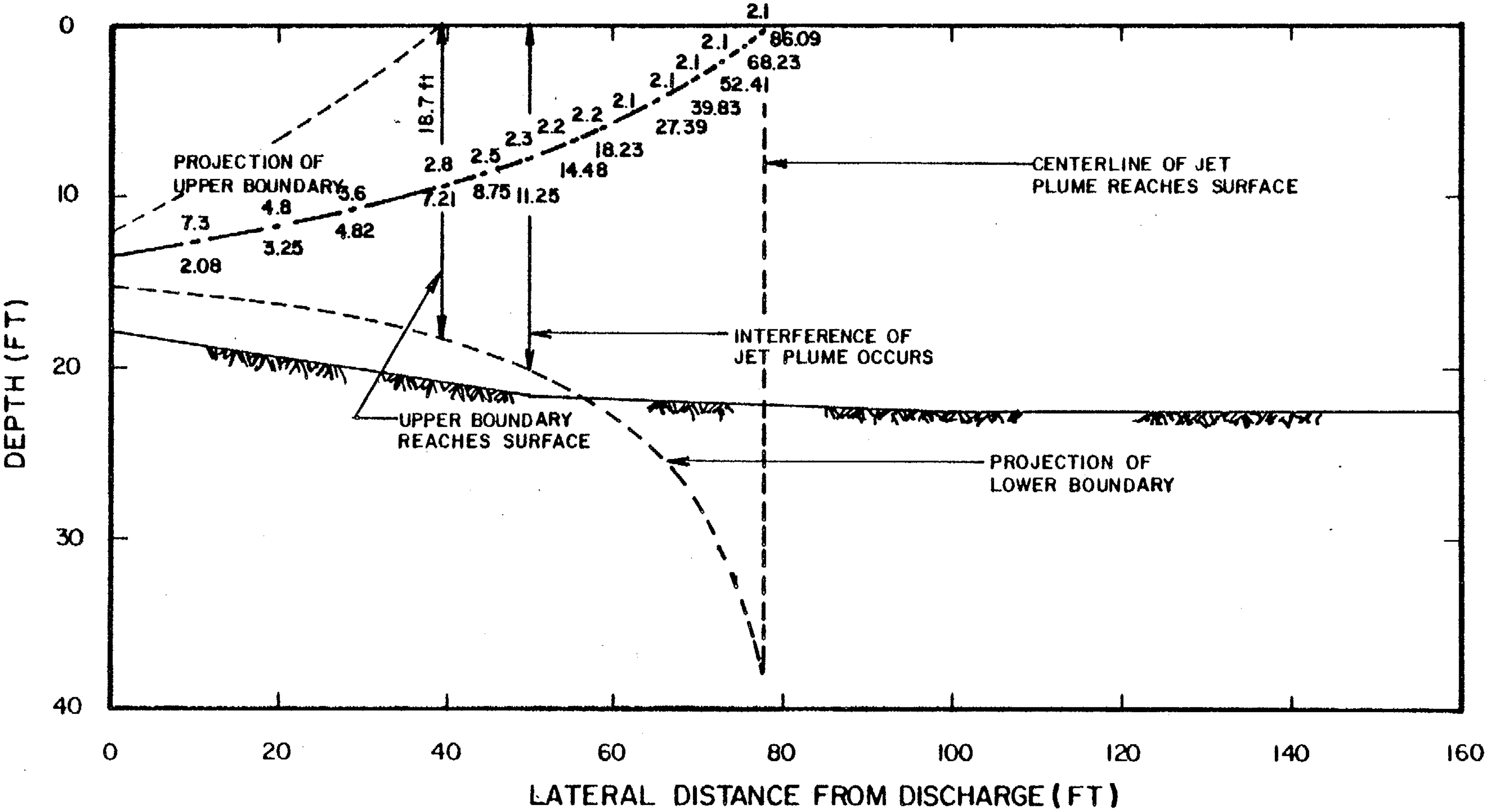


FIGURE V-17

SUBMERGED DISCHARGE DURING FLOOD

BOWLINE POINT GENERATING STATION

RIVER VELOCITY = 1.35 FPS

℄ DEPTH OF SUBMERGENCE = 16.5 FT

∢ X = 5°

AMBIENT TEMPERATURE = 79°F

DISCHARGE TEMPERATURE = 94° F

2.4 = JET VELOCITY (fps)

— — — = CENTERLINE

3.57 = DILUTION RATIO

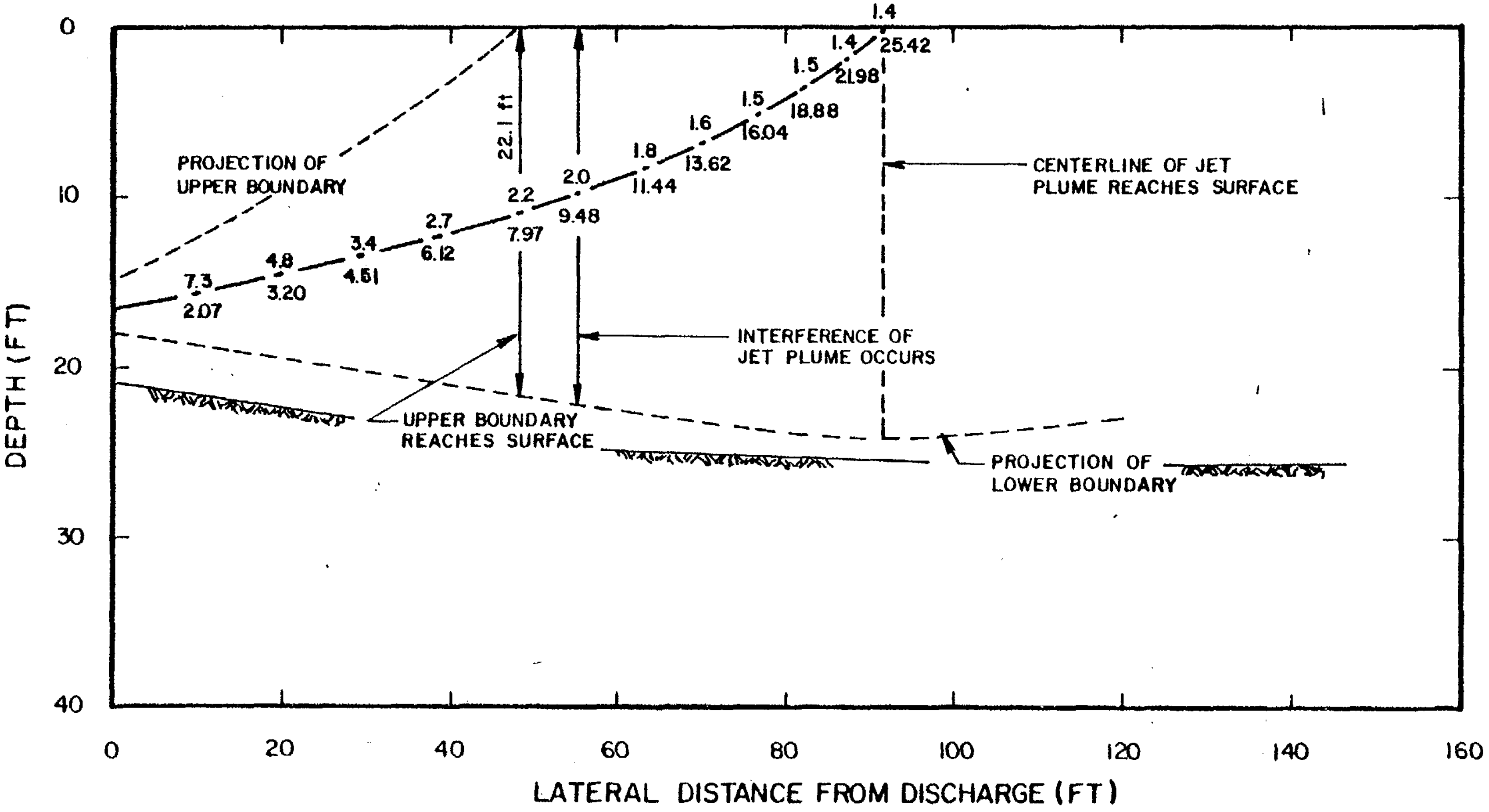


FIGURE 4-18

that submerged discharges with a dimensionless water depth (H = submergence/ port diameter) of less than 10 should have very small effective water depth, i.e., the depth of water in which the discharge effectively mixes. Bowline Point, with H = 4.5-5.5, should have little effective water depth and after the initial mixing would appear to be limited in the amount of dilution water that is available.

Using the submerged jet model results and the average field dilutions, effective water depths of 1.25, 2.0, and 2.25 ft were calculated for flood, ebb and slack tidal conditions, respectively. Small effective depths such as these are in the range of what might be expected from Robideau studies and would indicate that all the dilution (2-6) for the Bowline discharge occurs within the first 20-30 ft from the port and that after this point the plume bubbles to the surface with little additional dilutions (Figure 4-19). Accordingly, the velocity would decrease from 15 fps to about 4 fps within this region and probably decrease to ambient current or 2 fps at the surface.

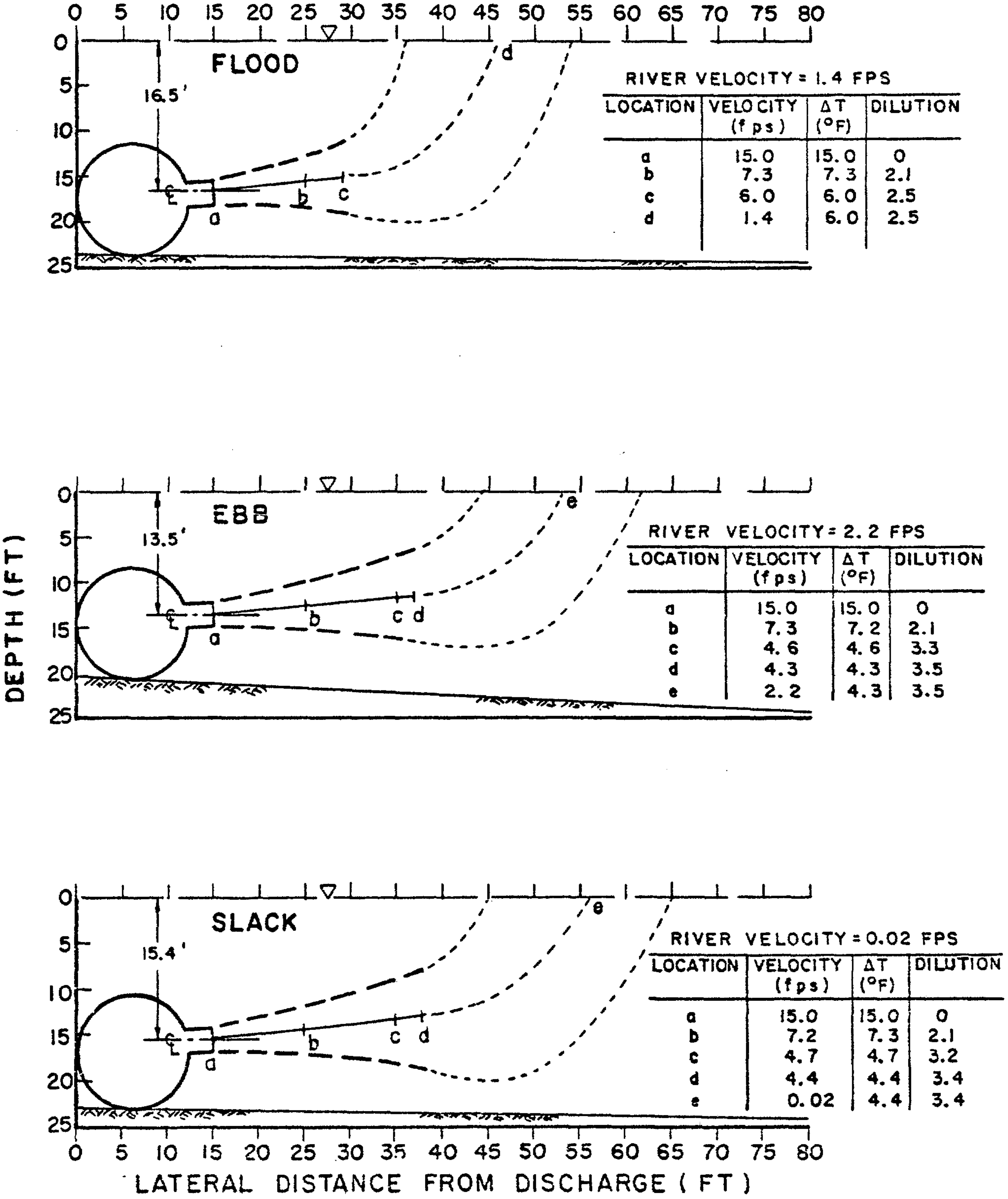
4.4 MATHEMATICAL MODEL STUDIES

4.4.1 Introduction

The four mathematical models used to predict the near-field and overall temperature distribution from the Bowline Point discharge are briefly described in this chapter, along with the model predictions. These models were used before the plant began operation to determine the best discharge structure and effect on the river temperatures. For detailed information concerning the derivation of these models, the following references should be consulted:

CORRECTED JET ANALYSIS OF SUBMERGED DISCHARGE

BOWLINE POINT GENERATING STATION



FLOOD — RIVER VELOCITY = 1.4 FPS

LOCATION	VELOCITY (fps)	ΔT (°F)	DILUTION
a	15.0	15.0	0
b	7.3	7.3	2.1
c	6.0	6.0	2.5
d	1.4	6.0	2.5

EBB — RIVER VELOCITY = 2.2 FPS

LOCATION	VELOCITY (fps)	ΔT (°F)	DILUTION
a	15.0	15.0	0
b	7.3	7.2	2.1
c	4.6	4.6	3.3
d	4.3	4.3	3.5
e	2.2	4.3	3.5

SLACK — RIVER VELOCITY = 0.02 FPS

LOCATION	VELOCITY (fps)	ΔT (°F)	DILUTION
a	15.0	15.0	0
b	7.2	7.3	2.1
c	4.7	4.7	3.2
d	4.4	4.4	3.4
e	0.02	4.4	3.4

Mathematical Model	Reference
The Single Submerged-Jet Model	QLM 1969, 1971
The Upper Layer Thermal Model	QLM 1971
The Multi-Segment Model	Lawler 1973
The Exponential Decay Model	QLM 1971

The results of the mathematical model predictions appear in Section 4.4.6 of this chapter.

4.4.2 The Single Submerged-Jet Model

The single submerged-jet model, which describes the behavior of a thermal effluent discharged through a submerged port, consists of a set of twelve simultaneous equations and incorporates the effects of: plant intake temperature and density; plant outfall temperature, density and flow; outfall geometry, including port size, shape edging, orientation and submergence; and river velocity, ambient temperature and density.

Based on the momentum conditions applying to the jet, a group of momentum equations can be written for the x, y and z directions (Figure 4-20); the equation for momentum normal to the jet axis can also be written. Expansion of the jet, determined experimentally, leads to three more equations, and density-temperature relationships and heat and mass balances complete the set of equations necessary for solution. The complete development of the total set of twelve equations is beyond the scope of this report. The necessary input parameters, however, are shown in Figure 4-21.

The submerged-jet model was used to evaluate the design of the discharge facility and to determine the compliance with the 90 F maximum surface temperature criterion. Although useful in preoperational studies, the model was supplanted and corrected (Section 4.3) by field data once the station began operation.

FIGURE 4-20

SUBMERGED DISCHARGE MODEL DEVELOPMENT

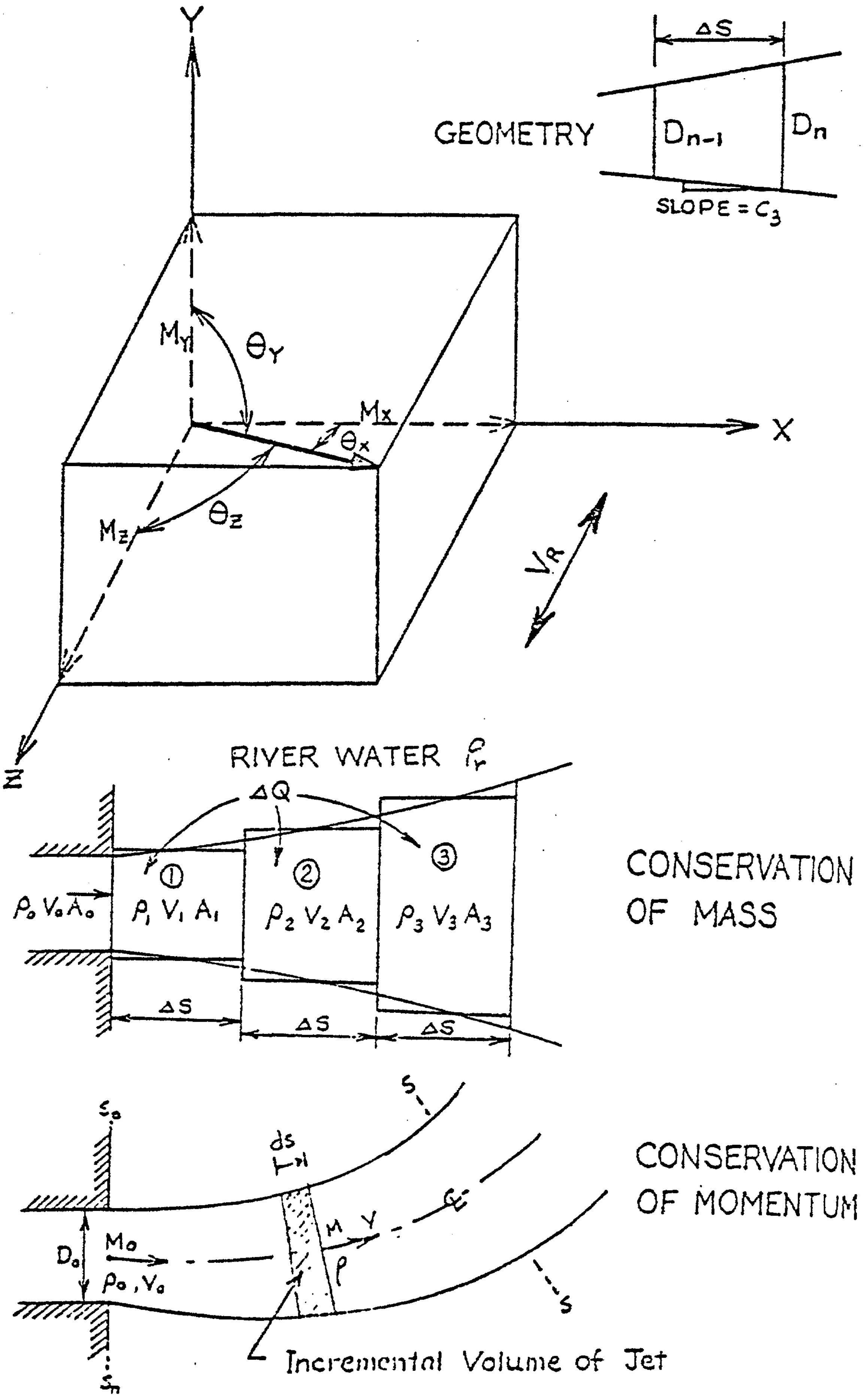
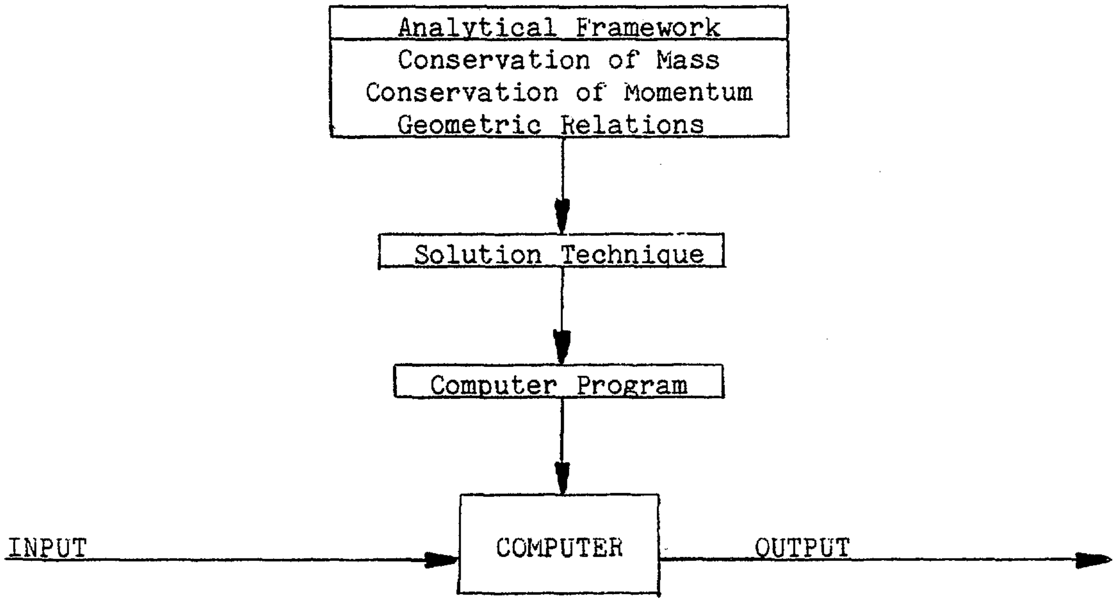


FIGURE 4-21

SUBMERGED DISCHARGE ANALYSIS
FLOW SHEET



- Port size
- Jet initial velocity
- Depth of submergence
- Orientation of port
- Maximum temperature of heated liquid
- Mass density of effluent
- Port coefficients
- Ambient temperature
- River velocity
- Mass density of river water

- Path of jet
- Jet velocity
- Jet size
- Mass density of jet

- Dilution ratio
- Jet temperature

4.4.3 The Upper-Layer Thermal Model

Upper-layer models (Lawler 1973) make use of the net non-tidal flow that exists in partially stratified estuaries such as the Hudson; these estuaries are subject to a net upstream movement of seawater in their lower layers and a downstream movement in their upper layers. This movement is induced by density differences caused by the vertical and longitudinal distribution of salinity. This effect is often called the net non-tidal flow, but must be distinguished from the freshwater runoff, which is the actual difference between total upstream and downstream tidal movement.

A mathematical model which uses the upper layer flow as the source of dilution for thermal discharges was developed. The defining differential equation for the longitudinal temperature distribution in the upper layer, seaward-directed flow is:

$$\frac{d}{dx}\left[Q_u \Delta\overline{T}_u\right] + \left(\frac{\overline{K}}{\rho C_p}\right)\left(B \cdot F\right) \quad \Delta\overline{T}_u = 0 \tag{4.4-1}$$

in which:

x = distance downstream from discharge (ft)

$Q_u(x)$ = upper layer, seaward-directed flow (cfs)

$\Delta\overline{T}_u(x)$ = average temperature rise over the upper layer (F)

$(\overline{K}/\rho C_p)$ = thermal decay coefficient (ft/sec)

$B(x)$ = river surface width (ft)

$F(x)$ = $\Delta\overline{T}_s/\Delta\overline{T}_u$, upper-layer thermal stratification factor (TSF), dimensionless.

$\Delta T_s(x)$ = surface average temperature rise (F).

Linear functions were developed for the terms B(x), $Q_u(x)$ and F(x) and incorporated in the model (QLM 1971). The resulting model is capable of calculating the average temperature rise over the upper level as a function of distance. This model was used to calculate the area-average temperature rise and the area-average surface temperature rise in the river as caused by the Bowline Point thermal discharge alone and in conjunction with the discharge from the Lovett and Indian Point plants. These results were then used with an exponential decay model (see below) to predict the percent surface width and cross-sectional area encompassed by the 4 F (2.2 C) isotherm.

Because this model was an early developmental version and the results are comparable to those of later thermal models, this model was essentially replaced by the more refined multi-segment model (see below).

4.4.4 The Multi-Segment Model

The multi-segment model is a one-dimensional, steady-state temperature model which accepts up to 27[a] thermal discharges along the estuary. Since the river in this model is segmented into 28[a] reaches, the model permits introduction of more realistic values for the space-variable parameters along the estuary. It has been demonstrated that the multi-segment model results agree very well with the results predicted by the upper layer thermal model (Lawler 1973).

---

[a] Updated November 1975 to include 38 thermal discharges and 39 reaches.

Because this model is capable of producing an area-average temperature rise and surface average temperature rise along the whole length of the Lower Hudson River as caused by any number of discharges, it is useful in determining the interaction between power plants, particularly, in this case, the effect of the Indian Point and Lovett thermal discharges on the temperatures near Bowline Point. These results are used with the exponential decay model (see below) to predict the percent area or surface width encompassed by the 4 F isotherm.

In the multi-segment model, the differential equation governing the heat transport in each segment is:

$$E_i \frac{d^2\overline{\Delta T}_i}{dx^2} - \frac{Q_i}{A_i}\frac{d\overline{\Delta T}_i}{dx} - \frac{\overline{K}_i B_i (TSF)_i}{\rho C_p A_i} \overline{\Delta T}_i = 0 \qquad (4.4\text{-}2)$$

where:

$\overline{\Delta T}$ = tidal-smoothed, area-averaged temperature rise (F)

E = longitudinal dispersion coefficient (mi^2/day)

$\overline{\Delta T}_s$ = surface average temperature rise (F)

ρ = water density (lb/ft^3)

C_p = heat capacity (Btu/lb/F)

i = segment subscript; $i = 1, 2, 3, \ldots, n$ and $n = 28$

Q = river freshwater flow (ft^3/day)

A = cross-sectional area of the estuary (ft^2)

K = heat transfer coefficient (Btu/ft^2/day/F)

B = top width of the estuary (ft)

TSF = thermal stratification factor ($\overline{\Delta T}_s/\overline{\Delta T}$)

The general solution of this second-order ordinary differential equation is:

$$\overline{\Delta T}_i(x) = C_i e^{J_i x} + D_i\, e^{K_i x} \qquad (4.4\text{-}2)$$

in which:

$$\left.\begin{matrix}J_i\\ K_i\end{matrix}\right\} = \frac{Q_i}{2A_iE_i}\left[1 \pm \sqrt{1+\frac{4K_iB_i(TSF)_iE_iA_i}{\rho C_p\, Q_i^2}}\,\right]$$

where:

C_i and D_i = integration constants

Since Equation 4.4-2 does not contain a term for the heat load, H_i, it is not applicable across the segment boundaries. Consequently, for an n-segment system, n equations of the form of Equation 4.4-2 are necessary to describe temperature behavior along the studied section of an estuary. The integration constants are evaluated by applying the following boundary conditions:

1. $\overline{\Delta T}\Big|_{x=0} = 0$

2. $\overline{\Delta T}\Big|_{x=\sum_{i=1}^{n} L_i} = 0$

3. $\overline{\Delta T}_i\Big|_{x=\sum_{i=1}^{n} L_i} = \overline{\Delta T}_{i+1}\Big|_{x=\sum_{i=1}^{n} L_i}$

   $i = 1,2,3....,(n-1)$

4. $H_i = \rho C_p\left[E_i A_i \dfrac{d\overline{\Delta T}_i}{dx} - E_{i+1} A_{i+1} \dfrac{d\overline{\Delta T}_{i+1}}{dx}\right]_{x=\sum_{i=1}^{n} L_i};$

   $i = 1,2,3....,(n-1)$

where: L = segment length (miles).

In the computer program, matrix inversion was used to solve the resulting simultaneous equations. After the computation of $\overline{\Delta T}$, the surface average temperature rise, $\overline{\Delta T}_s$, is computed by the following equation:

$$\overline{\Delta T}_s = TSF \cdot \overline{\Delta T}$$

4.4.5 The Exponential Decay Model

The exponential decay model permits conversion of the cross-sectional average behavior, predicted by either the upper-layer thermal model or the multi-segment model, to local behavior.

The exponential model for attenuation of temperature rise across the plane of discharge is:

$$\Delta T = \Delta T_m e^{-Ka} \qquad (4.4\text{-}3)$$

in which:

ΔT = temperature rise isotherm (F)

ΔT_m = maximum temperature rise at any point in the cross section (F)

a = that portion of the cross section within which the temperature rises equal or exceeds ΔT (sq ft)

K = exponential decay coefficient for area (sq ft^{-1})

Similarly, the exponential model for temperature attenuation across the surface width is:

$$\Delta T_s = \Delta T_{sm} e^{-kb} \qquad (4.4\text{-}4)$$

in which:

ΔT_s = surface temperature rise isotherm (F)

ΔT_{sm} = maximum surface temperature (F)

b = that portion of the surface width within which the surface temperature rises equal or exceed ΔT_s (ft)

k = exponential decay coefficient for surface width (ft^{-1})

The exponential decay coefficients, K and k, are found by recognizing that the curves given by equations (4.4-3) and (4.4-4) can be uniquely defined if the maximum and average temperature rises and the total cross-sectional area, A, and surface width, B, are known. The area-average and surface-average temperature rises are respectively:

$$\overline{\Delta T} = \Delta T_m \frac{1}{KA} (1 - e^{-KA}) \tag{4.4-5}$$

$$\overline{\Delta T}_s = \Delta T_{sm} \frac{1}{kB} (1 - e^{-kB}) \tag{4.4-6}$$

The adjusted one-dimensional, area-averaged model is used to compute $\overline{\Delta T}$. The surface-average temperature, $\overline{\Delta T}_s$, is equal to $\overline{\Delta T}$ multiplied by the thermal stratification factor (TSF). Equations 4.4-5 and 4.4-6 are solved to obtain K and k. Equation 4.4-3 and 4.4-4 are then used to obtain the percentages of cross-sectional area (100 a/A) and surface width (100 b/B) corresponding to selected temperature rises, ΔT and ΔT_s.

4.4.6 Mathematical Model Results

Table 4-5 presents the preoperational mathematical model predictions of the river temperature distribution at Bowline Point due to the combined effects of the Indian Point, Lovett and Bowline Point generating stations. The values appearing in the table represent the maximum predictions obtained using the four models. A comparison of the predicted percent surface width (23-31%) and cross-sectional area (5-7%) bounded by the 4 F (2.2 C) isotherm with the state thermal criteria (67% surface width and 50% cross-sectional area) indicates that no violation of the criteria is expected to occur at the Bowline Point station. The maximum surface temperatures expected at Bowline Point were obtained by summing the predicted maximum surface temperature rises (5 to 7 F) (2.8 to 3.4 C), the recirculation above ambient temperature (1.0 F) (0.6 C), and the upriver effect above river ambient (1.5 F) (0.8 C). The maximum surface temperatures thus obtained ranged from 86.5 to 88.5 F (30.3 to 31.4 C)

TABLE 4-5: MATHEMATICAL MODEL PREDICTIONS DUE TO THE COMBINED EFFECT OF INDIAN POINT, LOVETT AND BOWLINE POINT GENERATING STATIONS ON THE TEMPERATURE DISTRIBUTION IN THE HUDSON RIVER

PARAMETER	MATHEMATICAL MODEL PREDICTIONS[b]	NYSDEC THERMAL DISCHARGE CRITERIA
Maximum Surface Temperature Rise (°F)	5 ~ 7	--
Recirculation Above Base Temperature (°F)	1.0	--
Upriver Effect Above Ambient Temperature (°F)	1.5	--
Maximum Surface[c] Temperature (°F)	86.5 88.5	90
% Cross-Sectional Area Bounded by the 4°F Isotherm	5 ~ 7	50
% Surface Width Bounded by the 4°F Isotherm	23 ~ 31	67

---

[a] Three units at Indian Point, five units at Lovett and two units at Bowline are assumed to be operated at their maximum rated capacity (QLM 1971).

[b] These values represent the maximum predictions obtained using the four thermal models.

[c] The assumed maximum river ambient temperature at Bowline Point is 79°F. These values also include upriver effect (1.5°F) and recirculation (1.0°F).

(based on a river ambient temperature of 79 F* [26.1 C]). Therefore, based on maximum mathematical model predictions, a violation of the maximum surface temperature criterion of 90 F at Bowline Point will occur only when ambient river temperatures reach or exceed 81.5 F (27.5 C). A comparison of the mathematical model results with the maximum observed field results (Section 4-2) shows the model predictions to be on the whole conservative. Field studies have never indicated a violation of the 90 F surface criterion at Bowline Point, a situation that would occur only during the rare combination of maximum plant capacity, minimum dilution, and river temperatures of 83.5 F (28.6 C).

Comparisons of the field survey cross-sectional temperatures and mathematical model predictions representing conditions that occurred during the field studies also indicate that the model predicts higher temperatures. These comparisons are given in LMS (1974, 1975a).

4.5 HYDRAULIC MODEL STUDIES

4.5.1 Introduction

To aid in the preoperational evaluation of the time-dependent, three-dimensional thermal patterns produced by the Bowline Point Generating Station, two hydraulic models (undistorted and distorted) were tested by Alden Research Laboratories (ARL).

The undistorted model (a model which has all dimensions scaled similarly) of the Bowline Point discharge facilities was used to investigate the near-field

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*See QLM 1971 for basis of 79 F ambient.

temperature behavior and to provide basic information to calibrate the discharge in the distorted model (a model in which one scale, usually the vertical depth, is proportioned differently). The distorted model, once calibrated, was then used to investigate the thermal patterns resulting from the rated capacity operation of Bowline Point Units 1 and 2, Indian Point Units 1, 2 and 3, and Lovett Units 1 through 5. The model was also used to investigate the influence of the proposed docking facilities and to determine the extent of recirculation. Both of these models were documented in detail in an earlier report (QLM 1971) and therefore further discussion will be limited to a presentation of the model results.

4.5.2 The Undistorted Model

This model was used to investigate:

Near-field temperature distribution
Maximum surface temperature rises
Flow patterns of the submerged jets
Calibration of the distorted model
Thermal discharge outfall design and hydraulics.

A brief discussion of the pertinent test results follows.

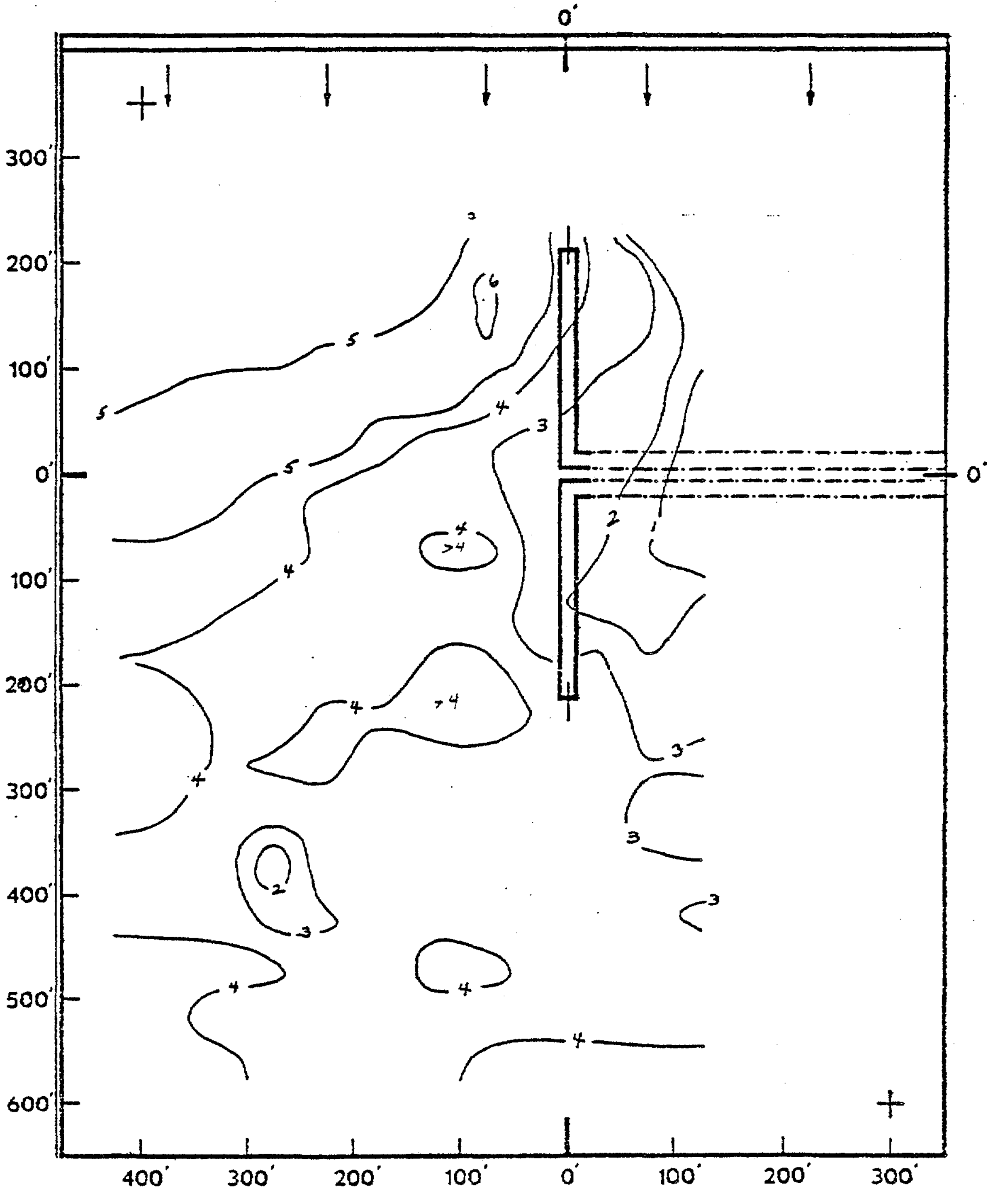
4.5.2.1 Near-Field Temperature Distribution

Several temperature distribution runs corresponding to river currents ranging from 0 to 1 fps (prototype) for the proposed Bowline Point plant were conducted by ARL. Figures 4-22 through 4-24 (QLM 1971) depict typical results representing temperature rises measured at 1, 8 and 15 ft below the water surface for

FIGURE 4-22

BOWLINE SUBMODEL COOLING WATER OUTFALL

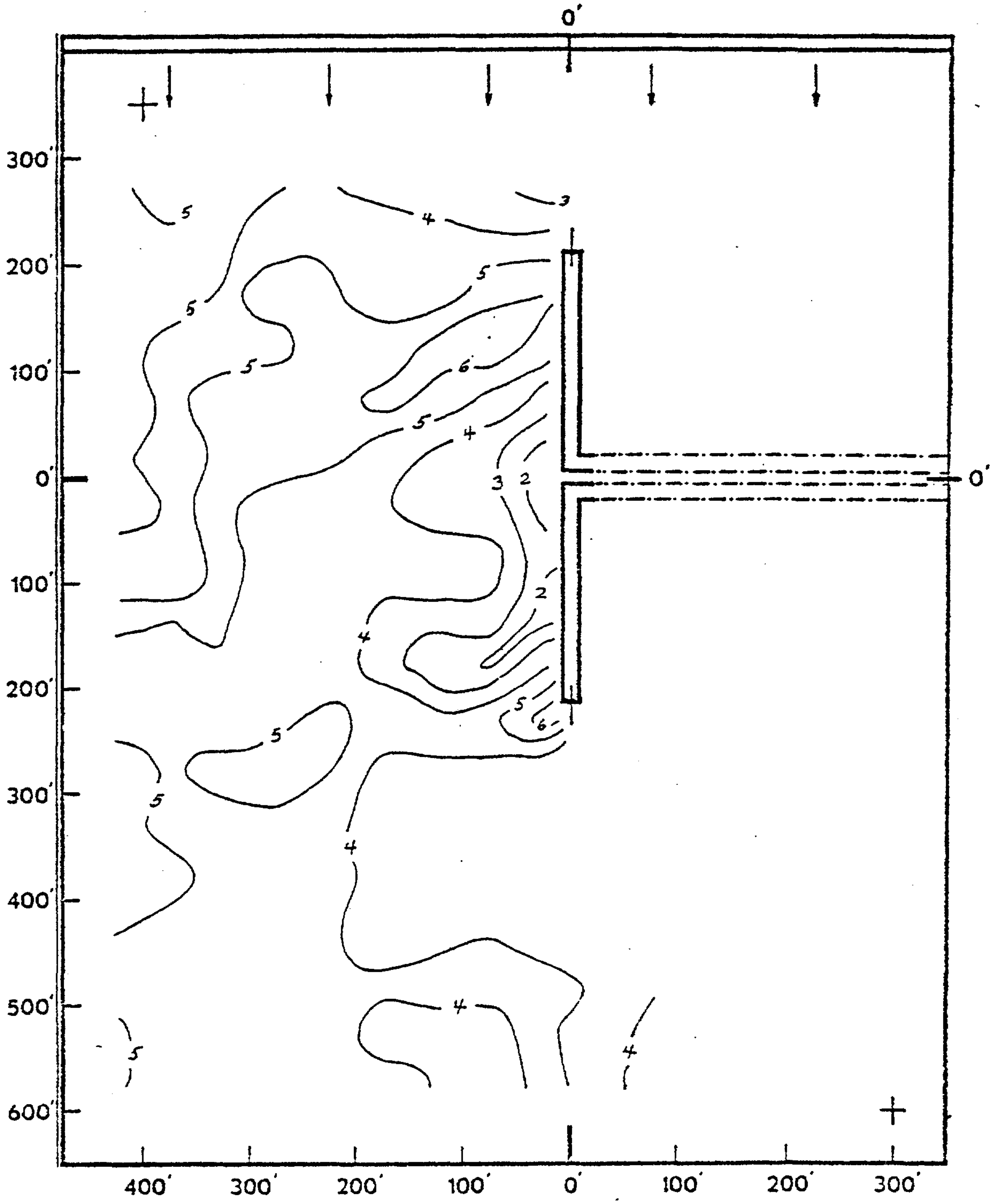
MODEL SCALE — 1:45



MODEL CONDITIONS	
Test No. & Date	203 ; 1-11 , 1971
River Ambient Temperature	72 °F
Discharge	1710 cfs
Depth of Isotherms	1'
River Current Velocity	0.45 fps
Temperature Rise	16 °F

BOWLINE SUBMODEL COOLING WATER OUTFALL

MODEL SCALE — 1:45



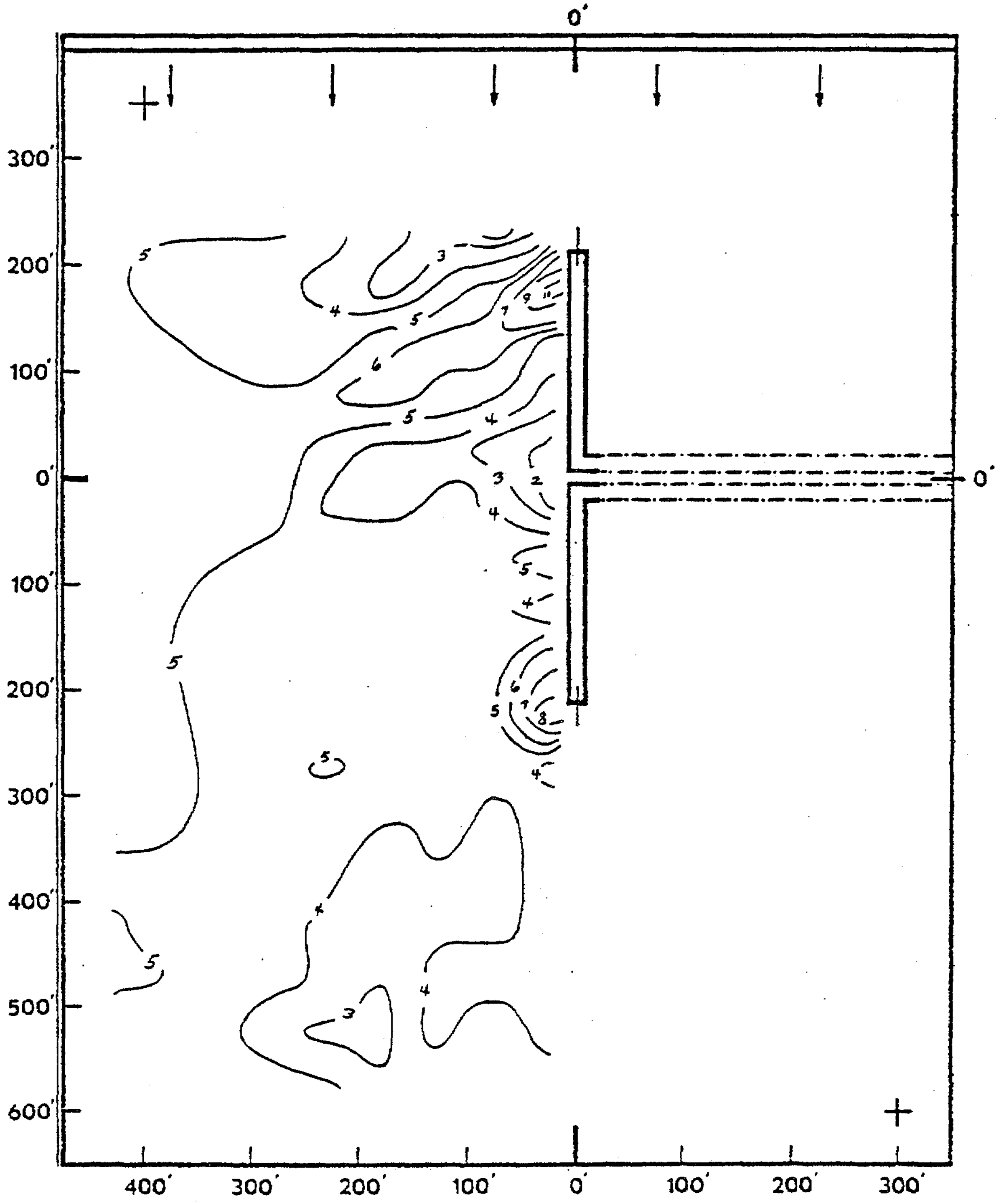
MODEL CONDITIONS

Test No. & Date 203 : 1-11, 1971
River Ambient Temperature 72 °F
Discharge 1710 cfs
Depth of Isotherms 8 '
River Current Velocity 0.45 fps
Temperature Rise 16 °F

FIGURE 4-24

BOWLINE SUBMODEL COOLING WATER OUTFALL

MODEL SCALE — 1:45



MODEL CONDITIONS	
Test No. & Date	203 : 1-11 . 1971
River Ambient Temperature	72°F
Discharge	1710 cfs
Depth of Isotherms	15'
River Current Velocity	0.45 fps
Temperature Rise	16 °F

two units at Bowline discharging 1,710 cfs (768,000 gpm) at a 15 F (8.3 C) temperature rise under river current velocity conditions of 1 fps.

The 1 fps river current velocity represents a long-term, summer mean (averaged over a tidal cycle) tidal velocity in the vicinity of the Bowline Point plant. At this velocity, the 1 fps model run showed:

a. A maximum surface temperature rise of 5 F (2.8 C) enveloping a surface area of about 8000 sq ft (0.184 acres).

b. A maximum lateral distance of approximately 400 ft from the outfall, representing about 3% of the surface width at Bowline Point subjected to a 4 F (2.2 C) temperature rise at the surface.

4.5.2.2 Maximum Surface Temperature Rises

Several runs were made consisting of continuous surface temperature measurements corresponding to river velocities ranging from 0 to 1 fps in the immediate area of the Bowline Point outfall. These runs were conducted to:

a. establish the transient behavior of the surface temperature rises

b. isolate the effect of the undistorted model boundaries

c. obtain the steady-state behavior of the surface temperature rises.

Table 4-6 summarizes the one-unit and two-unit operation results. The maximum surface temperature rise values represent the highest maximum temperature rises recorded during the runs before apparent plume reflection (boundary interference). The ARL results (Table 4-6) show that for current speeds of 1 fps, the dilution ratio associated with one-unit operation is almost the same as its two-unit operation counterpart (2.76 versus 2.70). For a river velocity

TABLE 4-6: BOWLINE UNDISTORTED MODEL SUMMARY OF MAXIMUM SURFACE TEMPERATURE RISES*

A. ONE UNIT OPERATION

1 RIVER CURRENT (fps)	2 PLANT TEMP. RISE (F)	3 COOLING WATER FLOW (cfs)	4 MAXIMUM SURFACE TEMP. RISE (F)	5 DILUTION RATIO (2/4)
1.0	15.2	855	5.5	2.76
0.5	14.2	855	5.2	2.73
0.5	15.2	855	4.9	3.10
0.0	17.5	855	4.1	4.27
0.0	13.0	855	2.7	4.82
MEAN	15.0	855	4.48	3.54
B. TWO UNIT OPERATION				
1.0	14.8	1710	5.5	2.70
0.75	14.7	1710	6.0	2.46
0.50	15.7	1710	4.6	3.42
0.45	15.0	1710	6.7	2.24
0.25	15.0	1710	5.9	2.54
MEAN	15.0	1710	5.74	2.67

---

*QLM 1971

of 0.5 fps, the two-unit operation dilution ratio is somewhat higher than the one-unit operation value (3.42 versus 3.1). Because of unavoidable boundary interference under two-unit operation and river velocities less than 0.5 fps, the stated dilution ratios are lower than expected; the results seem to indicate that under slack conditions two-unit operation would yield a dilution ratio of 4 or more.

4.5.2.3 Flow Pattern of the Submerged Jets

Photographic data involving dyes, etc., coupled with the predicted temperature measurements, supplied enough information to establish plume flow patterns for different river current velocities. Four one-unit operation profiles representing observed centerline plume trajectories corresponding to various river velocities are shown in Figure 4-25. These results indicate that no more than 12% of the surface width at Bowline Point would be affected by the thermal plume.

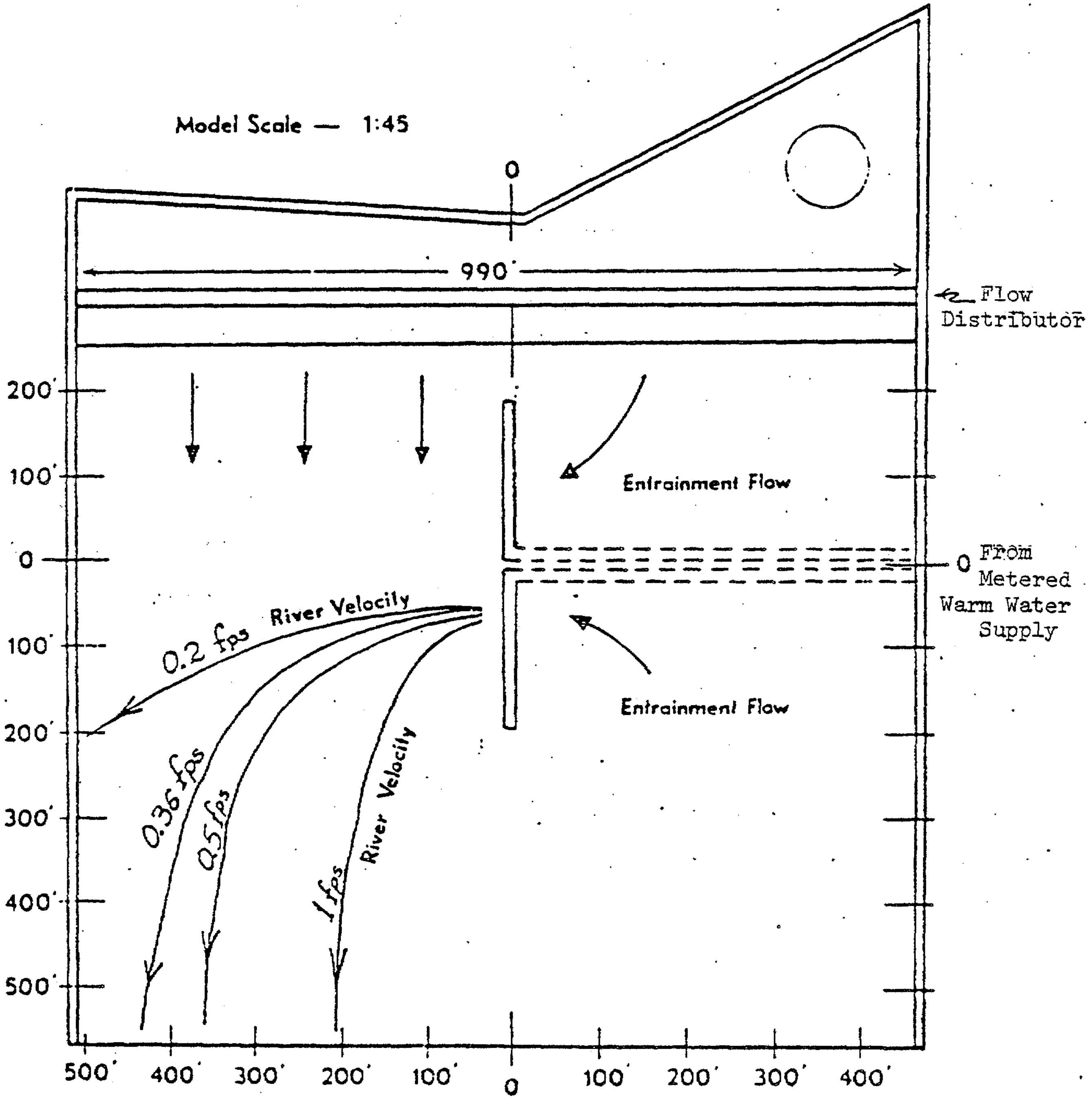
4.5.3 The Distorted Model

Consolidated Edison's Indian Point Model No. III was used to evaluate the effect of the Bowline Point station on the Hudson River. This model, which had a distorted vertical scale, i.e., it was scaled differently from the lateral and longitudinal scales, included the Bowline Point area as well as Indian Point. The distorted model was used to investigate:

- the influence of the docking facilities
- the extent of recirculation
- the thermal patterns resulting from the operation of two units at Bowline Point, three units at Indian Point, and five units at Lovett

UNDISTORTED HYDRAULIC MODEL FOR

BOWLINE SUBMERGED COOLING WATER OUTFALL



OBSERVED CENTER LINE TRAJECTORIES
WITH VARIOUS RIVER CURRENTS

The model results indicated that the docking facilities had an insignificant effect on the plume movement. A detailed description of the tests and results is presented in QLM (1971).

Figure 4-26 depicts two representative Bowline intake temperature profiles. These profiles correspond to rated capacity operation of five units at Lovett and two units at Bowline and stretch capacity operation of three units at Indian Point totaling 550 BBtu/day. These results indicate that continuous rated capacity operation of all existing and proposed plants in the area will result in a maximum recirculation at Bowline of 1.5 F (0.8 C) for the surface layer and 1.0 F (0.6 C) for the bottom layer, with an average of about 1 F (0.6 C).

The distorted model runs consisted of simultaneous rated capacity operation of the three plants under steady-state conditions and a drought river freshwater flow of 4,000 cfs. Table 4-7 summarizes the model results and compares them with the results of the mathematical analysis presented in Section 4.4.

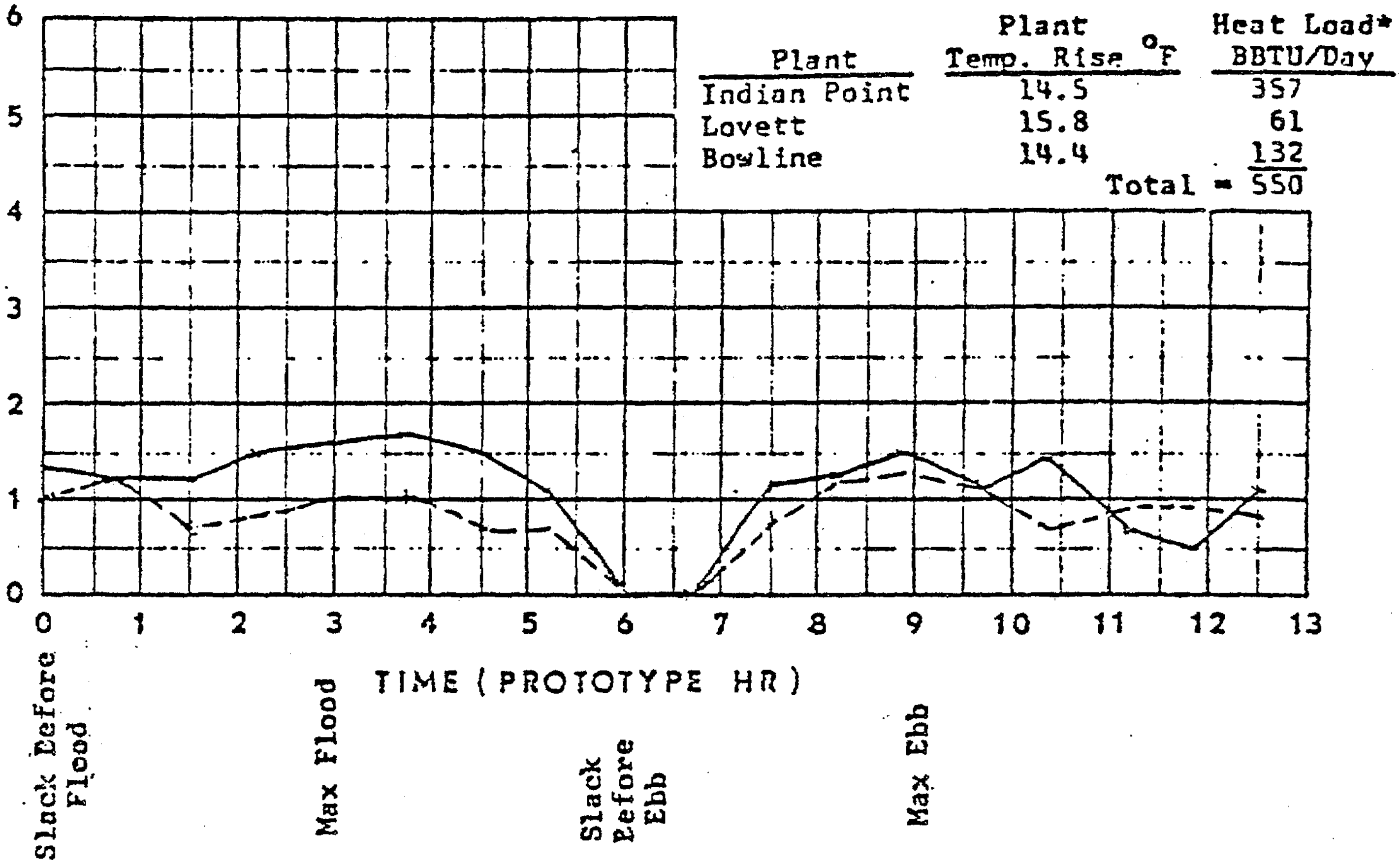
Table 4-8 compares the distorted model with the undistorted counterparts.

4.6 COMPARISON OF MATHEMATICAL AND HYDRAULIC MODEL PREDICTIONS AND FIELD SURVEY RESULTS WITH THE NEW YORK STATE THERMAL CRITERIA

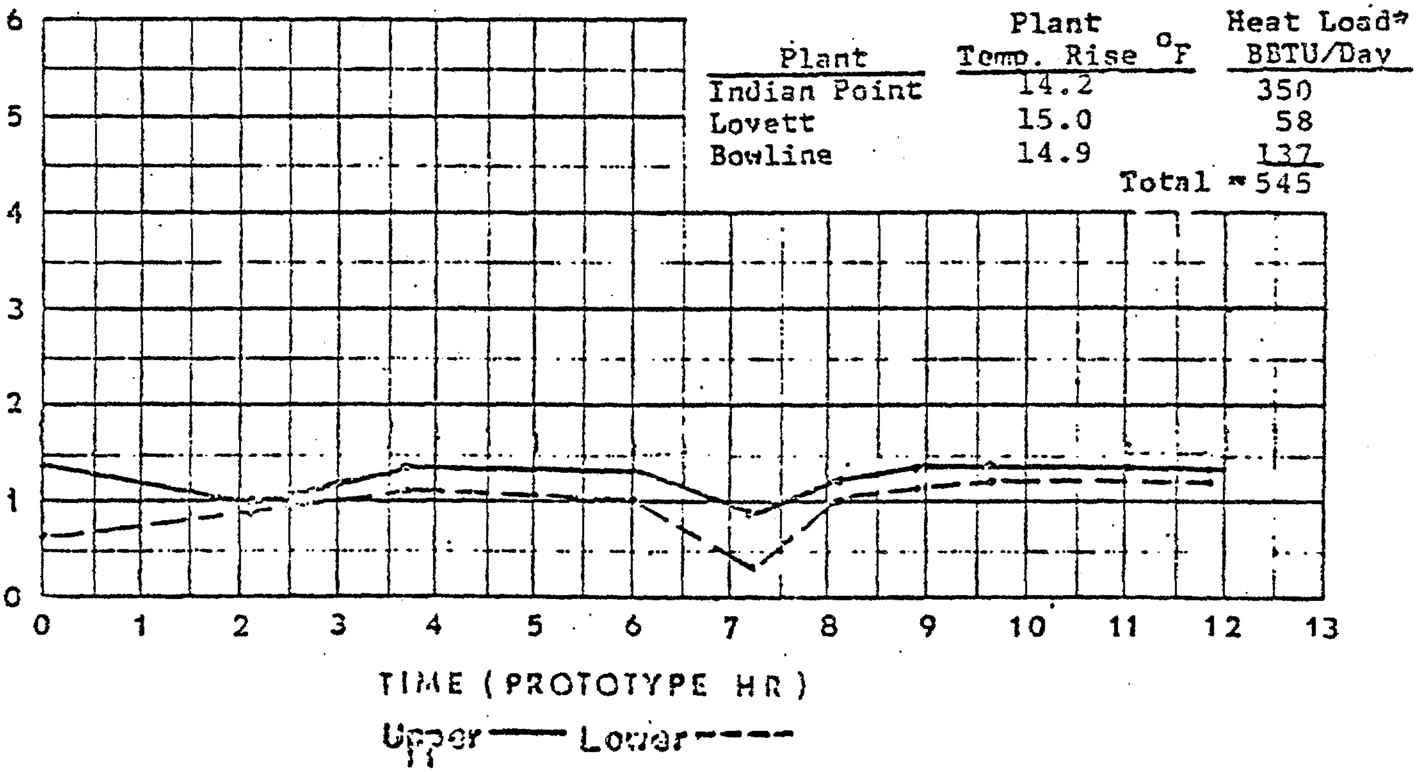
Table 4-9 presents the various thermal parameters as predicted by mathematical and hydraulic models and actual field observations. The model predictions were obtained using maximum plant operating conditions. The values listed under the field observations represent the maximum values observed for all triaxial thermal surveys conducted (1972-1975). Maximum surface temperatures

FIGURE 4-26

EFFECT OF RATED CAPACITY OPERATION OF 3 UNITS @ INDIAN POINT, 5 UNITS AT LOVETT & TWO UNITS @ BOWLINE ON BOWLINE INTAKE TEMPERATURE



Plant	Plant Temp. Rise °F	Heat Load* BBTU/Day
Indian Point	14.5	357
Lovett	15.8	61
Bowline	14.4	132
	Total =	550



Plant	Plant Temp. Rise °F	Heat Load* BBTU/Day
Indian Point	14.2	350
Lovett	15.0	58
Bowline	14.9	137
	Total =	545

otal Rated Capacity Heat Load = 550 BBTU/Day
(IP=369, L=57, B=124)

(QLH 1971)

TABLE 4-7: DISTORTED HYDRAULIC MODEL RESULTS - RATED CAPACITY OPERATION OF LOVETT, INDIAN POINT & BOWLINE POINT GENERATING STATIONS[a]

PARAMETER	HYDRAULIC MODEL RESULTS AT BOWLINE (Hours After LWS at Croton Point[b])									Mathematical Model Predictions
	0	2.1	3.6	6.0	7.2	8.1	8.8	9.6	11.8	
Maximum surface temperature rise (F)	4	4	4	5	3	5	4	5	5	5 to 7[c]
Maximum % surface width bounded by 4 F	4	3	4	6	0	5	10	3	4	23 to 31
Recirculation above base temperature (F)	1.05	0.95	1.25	1.2	0.6	1.15	1.3	1.35	1.35	2.5[d]
Surface area bounded by 4 F (acres)	15.4	4.85	7.34	13.2	0	25.0	14.7	43.7	30	
Location of plume (ft) from West Bank	1200	1000	800	840	880	720	880	1200	800	

---

[a] QLM 1971

[b] Lag time between Bowline and Croton Point is 10 minutes for slack and 15 minutes for maximum current strength.

[c] These values do not include recirculation or upriver effect.

[d] Includes 1 F Bowline recirculation and 1.5 F upriver effect.

TABLE 4-8: COMPARISON OF UNDISTORTED AND DISTORTED HYDRAULIC MODEL RUNS

PARAMETER	UNITS	UNDISTORTED MODEL	DISTORTED MODEL HOURS AFTER LWS AT CROTON POINT[a]			
			0	2.1	3.6	6
Maximum surface isotherm value	F	5	4	4	4	5
Location of plume[b]	ft	600	1200	1000	800	840
Surface area bounded by 4 F[c]	acres	2	15.4	4.85	7.34	13.2

---

[a] These values represent four flood phases observed during the flood cycle and were used since the undistorted model values correspond to a mean flood condition of 1 fps. Of these four columns the river flow corresponding to the 3.6 hours values is closer to the 1 fps flow condition than the other three sets. Therefore, their use for comparison with the undistorted model results is more valid.

[b] Plume location is defined as the horizontal surface distance between the diffuser and the center of the plume.

[c] A wider grid system was used in the distorted model, i.e., temperatures higher than those listed above may have occurred between grid points.

TABLE 4-9: COMPARISON OF MATHEMATICAL AND HYDRAULIC MODEL PREDICTIONS AND FIELD RESULTS DUE TO THE COMBINED EFFECT OF INDIAN POINT, LOVETT AND BOWLINE POINT PLANTS ON HUDSON RIVER TEMPERATURE DISTRIBUTION AT BOWLINE[a]

PARAMETER	MATHEMATICAL MODEL PREDICTIONS[b]	HYDRAULIC MODEL PREDICTIONS	FIELD OBSERVATION[c] (DATE)	NYSDEC THERMAL DISCHARGE CRITERIA
Maximum Surface Temperature Rise (F)	5 - 7	3 - 5	7.2 (18 JUN 75)	-
Recirculation Above Base Temperature (F)	1.0	0.6 - 1.35	-	-
Maximum Surface Temperature (F)	86.5 - 88.5[d]	82.6 - 85.35	84.7 (29 AUG 74)	90
% Cross-Sectional Area Bounded by the 4 F Isotherm	5 - 7	-	7.5 (18 AUG 75)	50
% Surface Width Bounded by the 4 F Isotherm	23 - 31	3 - 10	7.9 (18 AUG 75)	67

---

[a] Mathematical and hydraulic model predictions assume two units at Bowline Point, five units at Lovett, and three units at Indian Point are operating at their maximum rated capacity; predicted values are based on an ambient river temperature of 79 F and are taken from QLM (1971).

[b] These values represent the maximum predictions obtained using four mathematical models (LMS 1978:pp. 4-32 to 4-42), upriver discharges resulted in an additional 1.5 F temperature rise above ambient.

[c] These values represent the maximum field observations as obtained form all the triaxial thermal surveys (1972-1975).

[d] These values include a recirculation temperature rise of 1.0 F and a temperature rise of 1.5 F from upriver discharges.

were calculated for the models assuming a maximum river ambient temperature at Bowline Point of 79 F (26.1 C) (QLM 1971).

The mathematical model predicted values slightly higher than field observations while the hydraulic model compared well with the field data. Both models and the field results show maximum values less than the stipulated 90 F surface maximum temperature criterion. The maximum observed percentage of the cross-sectional area within the 4 F (2.2 C) isotherm at the plant was 7.5%, which is well within the state criterion of 50%. The mathematical model predicted values slightly below field observations. The hydraulic model did not predict cross-sectional areas of the $\geq$4 F (2.2 C) temperature rise isotherms. Although the maximum percentage of surface width (predicted) was 31%, this value is still much less than the state thermal criterion of 67%, the field data showed a maximum of 7.9%.

5. FAR-FIELD THERMAL EFFECTS

5.1 INTRODUCTION

Far-field thermal effects refer to the residual heat from a thermal discharge that is moved downstream after the initial mixing in the near field. It is in the far field that the majority of the artificially discharged heat is exchanged into the atmosphere, particularly in the cases of submerged discharges which enhance the mixing of effluent with the river water.

Far-field heat is difficult to measure in the field because of the extensive distance over which measurements must be taken, and the variations in river ambient or natural heat inputs which obscure the distinction between natural and artificial heat. Mathematical models are useful in analyzing the far-field effects because of the ease they permit in removing the artificial heat input.

5.2 MATHEMATICAL MODELS

A far-field, one-dimensional, multi-segment model was useful for analyzing the effects of the Bowline Point discharge and other discharges on the Hudson River. This model is described in Section 4.4, Mathematical Models.

5.3 RESULTS

Figure 5-1 shows the average river cross-sectional temperature rise profiles ($\Delta\overline{T}$) and surface average temperature rise ($\Delta\overline{T}_s$) predicted by the multi-segment model. These profiles were predicted with respect to individual discharges of the Roseton, Bowline Point and Indian Point Generating Stations. The combined effect of these plants, in additon to the Lovett and Danskammer Point stations, are presented in Figure 5-1. The model predicts a river cross-sectional,

COMBINED EFFECTS OF DANSKAMMER, ROSETON, INDIAN POINT, LOVETT, AND BOWLINE POWER PLANTS ON HUDSON RIVER TEMPERATURES
SEVERE SUMMER CONDITION

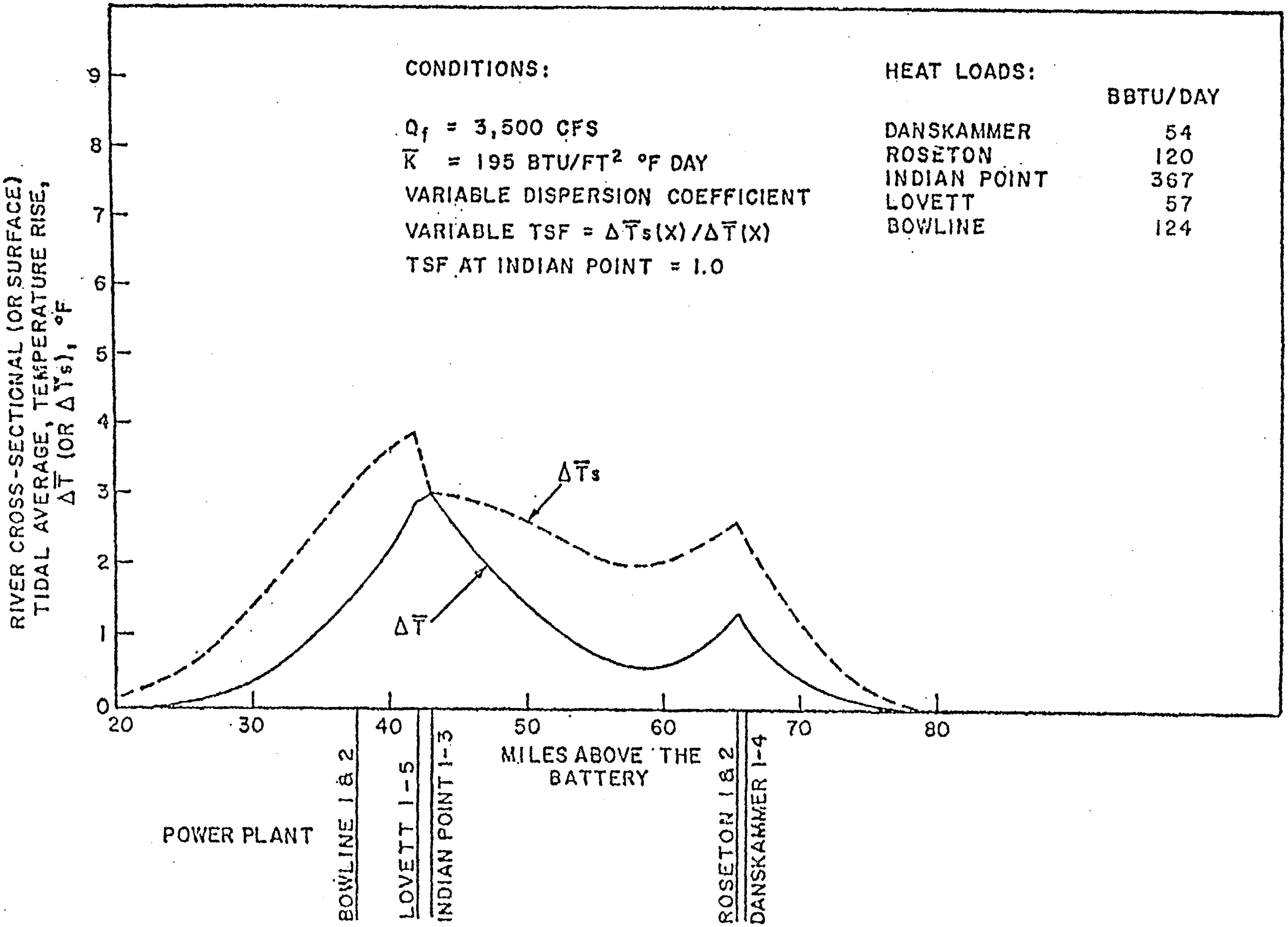


FIGURE 5-1

tidal-average temperature rise of approximately 0.4 F (0.2 C) for the Bowline Point station (see Lawler 1972) and 1.6 F (0.9 C) for the combined effect of five stations in operation at 100% load capacity.

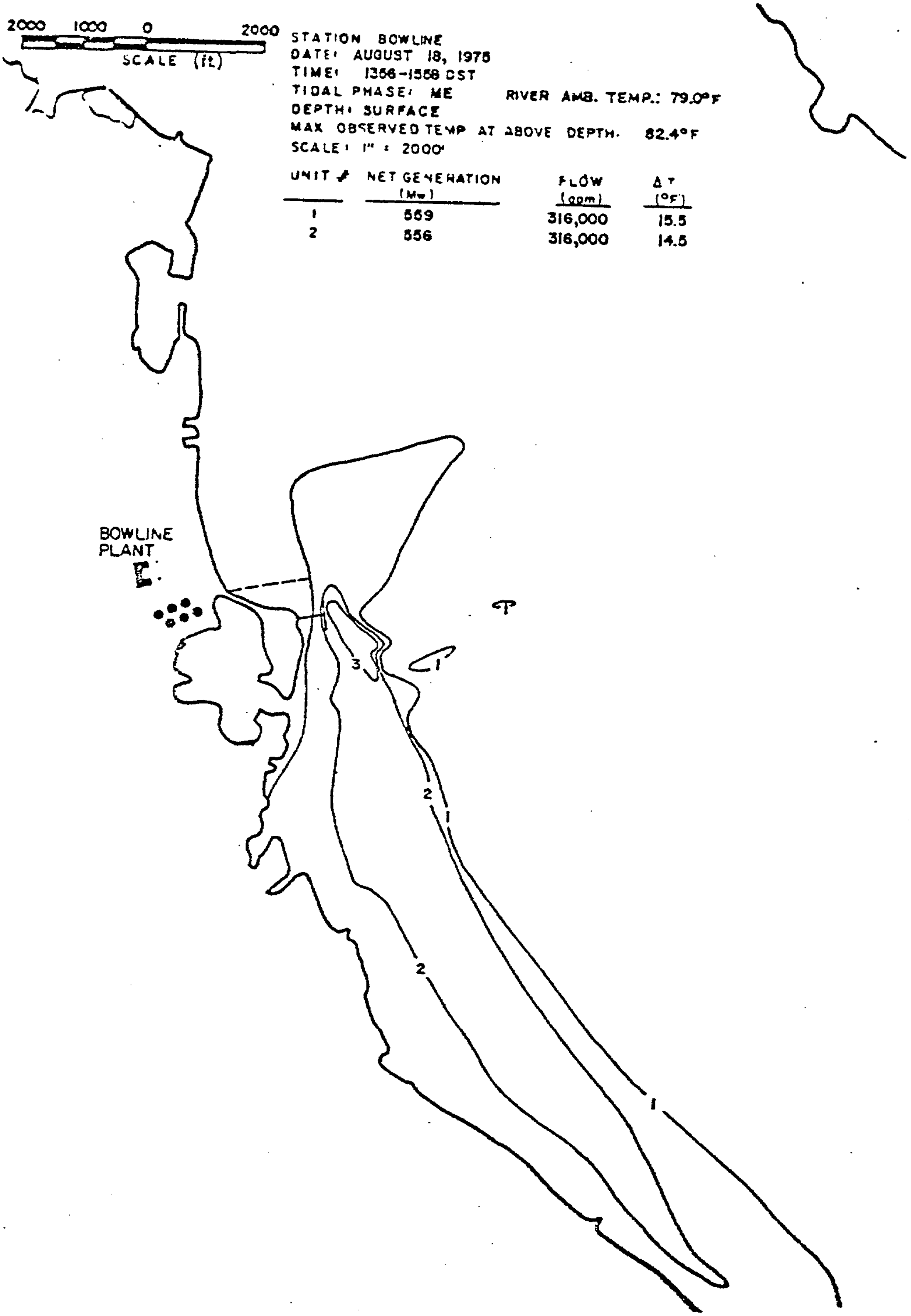
It should be noted that studies comparing the model predictions with actual observed data show that the model is conservative, i.e., predicts higher temperature rises (LMS 1974, 1975a). In addition, these data show the effect of the combined plants under drought flow and maximum plant operation, which represents the worst possible situation.

6. TIME-TEMPERATURE PROFILE FROM DISCHARGE PORT TO 1 C ISOTHERM

Only a preliminary time-temperature profile from discharge port to 1 C (1.8 F) isotherm can be calculated from available data. Field surveys have tracked the discharge plume only during certain time periods (usually 1-2 hours at a time) centered around slack or maximum current conditions. No continuous recording of the discharge water and/or its temperature decay has been performed, other than that associated with the near-field plume measurement during the thermal surveys. Thus, while the time-temperature profile can be tracked for one tidal phase, a gap exists between tidal phases, and it is not known whether or not a particle of water at a certain temperature is continued into the next measured tidal phase. Since the discharge plume occupies only a small portion of the river, and the area-averaged temperature rise above ambient is less than 1 C (1.8 F), it must be determined whether or not a water particle can be moved downriver or upriver with the plume and reverse direction with the tidal change, and still remain in the narrow band of water that encloses the plume.

For this analysis, the time-temperature profile will be assumed to be within one tidal phase and although the profile may continue for a short time into the next tidal phase, it will be quickly mixed and diluted below 1 C (1.8 F). Results of the thermal surveys appear to support this assumption, despite the gaps in the data.

A review of thermal surveys for the Bowline Point vicinity indicates that the longest plume occurs during maximum ebb, when the plume extends downriver for some distance. Figure 6-1 illustrates the surface plume as measured on 2 August 1974 during a maximum ebb tidal current; the surface plume is used in



STATION BOWLINE
DATE: AUGUST 18, 1976
TIME: 1356-1558 CST
TIDAL PHASE: ME RIVER AMB. TEMP.: 79.0°F
DEPTH: SURFACE
MAX OBSERVED TEMP AT ABOVE DEPTH. 82.4°F
SCALE: 1" = 2000'

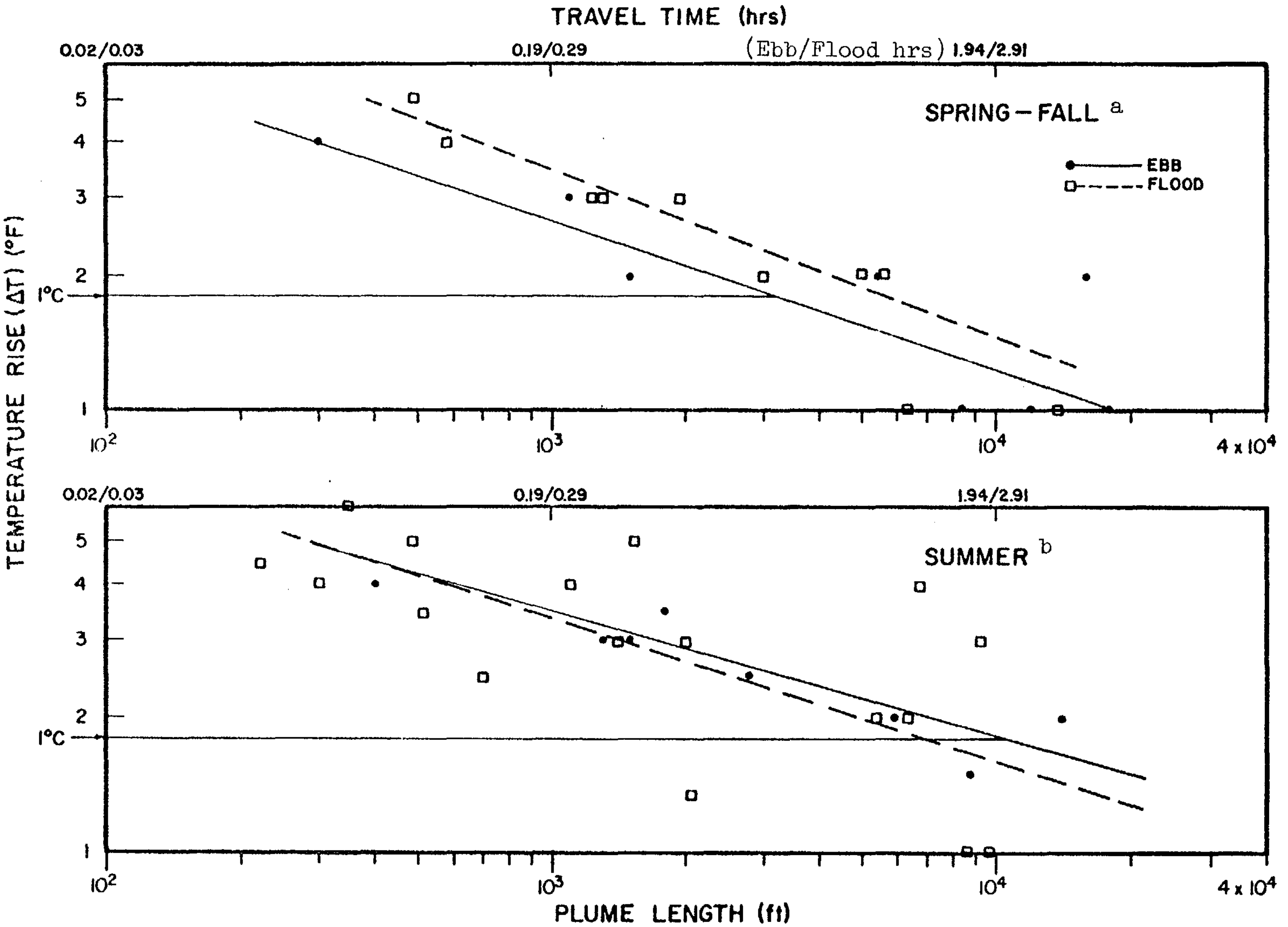
UNIT #	NET GENERATION (Mw)	FLOW (gpm)	ΔT (°F)
1	569	316,000	15.5
2	556	316,000	14.5

this analysis because it represents the longest and warmest plume. Similarly, thermal survey data (see Appendix) indicate that the surface plume during flood tide is also critical, although usually slightly warmer in the near field and cooler in the far field than during ebb tide. Figure 6-2 depicts the plume length vs. temperature rise above ambient during ebb and flood tide for seven thermal surveys and indicates that the plume length is dependent on seasonal conditions. As the bottom plot on Figure 6-2 indicates, the longest plume occurs during the summer. Using the plume distances as indicated on Figure 6-2, and average ebb and flood current velocities of 1.44 and 0.96 fps, respectively, Figure 6-3 illustrates the maximum time-temperature profile from the discharge to the 1 C (1.8 F) isotherm during spring-fall conditions and summer conditions.

The time-temperature plot (Figure 6-3) and previous analysis (Figure 4-19) indicate three mixing zones for the discharge; the first is the rapid initial dilution within the first 20 to 40 ft from the jet. In this zone the discharge temperature is diluted from the condenser-induced temperature rise to within 4 to 7.2 F above ambient; this occurs within 4-10 seconds of discharge. In the second zone the jet momentum is dissipated with some decrease in temperature rise; this zone occurs within 20-30 minutes from the discharge. The third zone covers the movement of the plume by tidal currents and the gradual decrease to ambient temperatures.

The minimum time in the heated plume is for a water particle (winter or summer) on the edge of the plume; this particle is mixed immediately with river water and goes from the discharge temperature (8.8 C, 15.8 F) to 1 C (1.8 F) within a few seconds.

TIME TEMPERATURE PROFILE
BOWLINE POINT GENERATING STATION

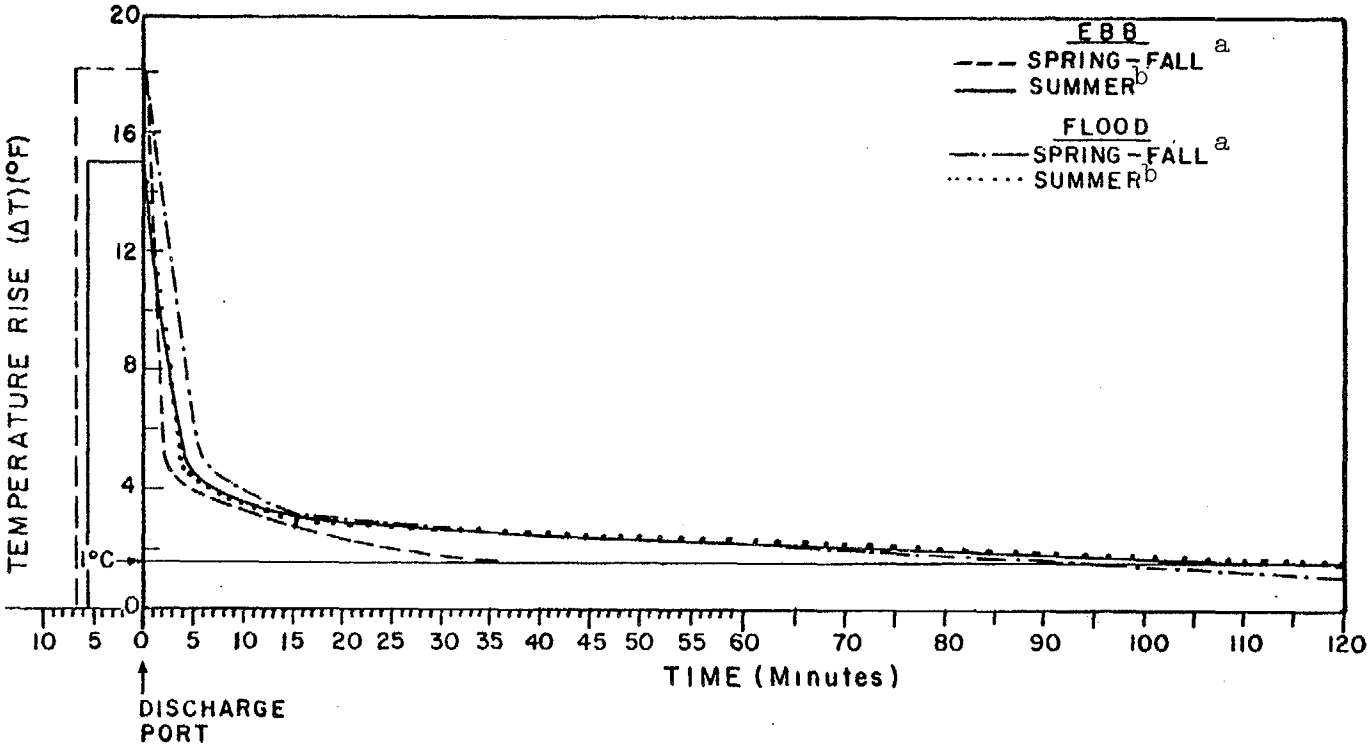


[a] NOV 1974, APR 1975, and OCT 1975

[b] 2 AUG 1974, 29 AUG 1974, JUN 1975, and AUG 1975

FIGURE 6-2

TIME-TEMPERATURE PROFILE
FROM INTAKE TO 1°C ISOTHERM.
BOWLINE POINT GENERATING STATION



[a] NOV 1974, APR 1975, and OCT 1975

[b] 2 AUG 1974, 29 AUG 1974, JUN 1975, and AUG 1975

FIGURE 6-3

7. RECIRCULATION

Recirculation can be defined as the process by which some portion of a discharge flow is drawn into a plant intake and passes through the circulating water system.

Estimates of recirculation at the Bowline Point plant were calculated by three methods: thermal field survey, dye study, and the mathematical slug method in O&R (1977). The results of these analyses will be summarized in this section.

The results of several thermal surveys at Bowline Point were used to calculate rates of recirculation. Only the most accurate temperature data were used, but even these had variability to +1 F (0.6 C), which translates to an accuracy of ±7% in recirculation rate (based on plant temperature rise of 15 F [8.3 C]). Using the available thermal data which cover a variety of plant flows, river temperatures, and freshwater flow, the average thermal recirculation was calculated as 12.9%, with a tidal variation as given below:

Tidal Phase	Percent Recirculation
Flood	11.9
High Water Slack (HWS)	13.2
Ebb	14.8
Low Water Slack (LWS)	11.6

Continuous dye injection (EAI 1977) into the Unit 1 discharge of Bowline Point Generating Station was used to simulate the thermal equilibrium achieved between the intake and discharge waters of the plant. Relationships based upon the continuity and mass balance equations were used to relate observed intake and discharge concentrations to the recirculation of cooling water. Over an average steady-state tidal cycle, recircultion varied from approximately 12% at low tide to 14.3% about halfway between low and high tide. The average recirculation was 13%.

This value is representative of recirculation during the survey, which was performed during normal plant pumping conditions (632,000 gpm for the total plant), summer ambient temperatures, and a relatively high freshwater flow for the time period (12,000-30,000 cfs measured at Green Island).

A theoretical estimate of recirculation for the Bowline Point plant was obtained using the slug method. The method was used for maximum capacity conditions as a tool to estimate parameters affecting recirculation. The conclusions are as follows:

1. Based on maximum cooling water flow the at Bowline Point plant (768,000 gpm) and a discharge mixing zone width of 800 ft from shore, the average recirculation was 19.8% (20.3% during ebb and 19.2% during flood).
2. The analysis showed that the major parameter governing the rate of recirculation was the lateral extent of the thermal discharge plume; doubling this distance decreased the recirculation by half. The width used was representative of the tight discharge pattern observed during the winter and agrees fairly well with the results of the field surveys (corrected for plant flow). This relationship of recirculation and discharge zone is important because it helps to explain the results obtained by the field thermal surveys.
3. The analysis also showed that recirculation is directly proportional to plant flow (e.g., doubling the plant flow doubles the recirculation). Although the model indicates a definite relationship, it does not account for conditions which may alter this relationship. For example, this far-field model is not applicable in the near field, and thus does

not account for the increased mixing and greater discharge zone associated with greater plant flow. It also does not account for slack tidal phases and possible direct recirculation. Thus, it is not possible to correct a half flow condition to full flow by doubling the percent of recirculation since an inverse relationship of increasing the discharge width must also be taken into consideration. The opposite effect of increased plant flow is that the discharge zone width is increased by the greater port velocity; by increasing the discharge zone the recirculation decreases. Theoretically, and supported by some field data, the overall change in the discharge zone due to changes in plant flow is not as great as the direct effect that can be traced to a change in the volume of water discharged. Thus it may be concluded that decreasing the plant flow will have an overall effect of decreasing the recirculation.

8. EFFECT OF BOWLINE POINT OPERATION ON RIVER DISSOLVED OXYGEN AND EFFECT OF CHLORINATION

8.1 DISSOLVED OXYGEN

A description of dissolved oxygen (DO) in the Hudson River is given in O&R (1977); this section will discuss the effect of the operation of Bowline Point on the river DO.

In order to estimate this effect, a mathematical model (Lawler 1972, 1973) was used to simulate in-plant DO losses through the power plant circulating water system. That model was then verified using DO measurements taken at the Bowline Point intake and discharge by LMS (1974, 1975b), and used to predict losses under maximum summer and winter river temperature conditions. Those results are presented below:

1. Based on the mathematical model (verified by field studies), the passage of cooling water through the Bowline Point station will reduce the DO concentration in that water by approximately 0.90-1.50 mg/l during the winter or early spring when the DO in the river is at its highest level (usually less than 100% saturation). There is a smaller decrease in DO, on the order of 0.02-0.97 mg/l (based on a plant flow of 316,000 gpm) during the summer.
2. As a result of the loss of DO in the circulating water, DO in the river at Bowline Point is reduced a maximum of about 0.08 mg/l (0.55% loss) during the winter, at an average flow of 24,000 cfs and by 0.16 mg/l (1.97% loss) during the summer, based on the seven-consecutive-day low flow of 3,500 cfs.

3. Since the in-plant DO losses are small and generally less than the natural fluctuations in DO, it is expected that the operation of the Bowline Point station will have an insignificant effect on the DO in the river.

8.2 CHLORINATION

Sodium hypochlorite (15% solution) is periodically added to provide chlorination of the cooling water, in order to minimize slime growth in the condenser (for a discussion of the chlorination system, see O&R 1977).

Under present operating conditions the condenser cooling water for each unit is chlorinated separately once each day for 30 minutes during the time interval when the water temperature of the Hudson River is above 50 F (10 C). This temperature is usually attained in late spring and typically remains above 50 F (10 C) through mid-fall.

Recent plant operations (1976 and 1977) has been such that the cooling system was chlorinated whenever slime growth became a problem, a situation that occurred infrequently. It is expected that the operating procedures will be altered to reflect this lack of slime growth and minimal use of chlorine. Until other changes are instituted, however, the expected procedure is for the chlorination rate described above to be continued, but only three times each week instead of daily. At this rate, 115.4 lbs/week of free residual chlorine will be discharged to the river, based on an average discharge concentration of free residual chlorine of 0.2 mg/l with a maximum of 0.5 mg/l.

Studies (LMS 1974, 1975a) at Indian Point and Bowline Point Generating Stations indicate an initial river chlorine demand of 0.8 mg/l at an initial laboratory test concentration of 2.5 mg/l, and therefore a chlorine demand to initial chlorine concentration ratio of 0.32; during other studies, ratios of 0.62 to 0.85 were observed. Based on a discharge concentration of 0.2 mg/l free residual chlorine and the various dilutions encountered in the plume, the concentrations of free residual chlorine in the plume are as follows:

FREE RESIDUAL CHLORINE (mg/l)

	RIVER DEMAND RATIOS	
Dilution Ratios	0.32	0.85
Initial Minimum = 1.6 (refers to Max. T_s)	0.1075	0.0838
Average Initial = 3.23	0.0425	0.0229
Dilution to 4 F = 3.75 (based on ΔT_o = 15 F)	0.0349	0.0173
Dilution of 2 F = 7.5 (based on ΔT_o = 15 F)	0.0140	0.0048

The above calculations of free residual chlorine do not account for the reduction of chlorine by ultraviolet light, a factor which may be significant especially since the residual chlorine will be in the thermal plume, which is basically a surface plume outside the diffuser area. Also the dilutions used in this analysis are based on steady-state assumptions while the actual discharge will represent at worst a one-hour dosage, three times weekly, if each unit is chlorinated back to back, or a half-hour dosage, six times weekly. A dosage discharge may have higher dilutions because there will be no residual buildup in the dilution water, i.e., the dilutions used in the thermal analysis are low because of recirculated heat from the continuous discharge of heat. In addition, the dilution values are based on either one-unit operation or two-unit operation with no discharge through one unit while the other is discharging flow with no concentration. Separate chlorination of each unit while the other unit is operating, should dilute the discharge concentration by half, although it was not taken into account in the above analysis.

Ultraviolet decay, other river demands, and dilution by the river flow will prevent any buildup of free residual chlorine in the river.

REFERENCES CITED

Ecological Analysts, Inc. 1977. Bowline Point Generating Station dye recirculation study. Prepared for Orange and Rockland Utilities, Inc.

Lawler, J.P. 1972. Testimony of John P. Lawler, Ph.D., Quirk, Lawler & Matusky Engineers, on the effect of Indian Point Units 1 and 2 operation on Hudson River dissolved oxygen concentrations. Testimony before the United States Atomic Energy Commission. Docket No. 50-247. November 13, 1972.

Lawler, J.P. 1973. Cumulative effects of Bowline Point, Roseton and Indian Point generating stations on the Hudson River. Testimony before the U.S. Atomic Energy Commission. Docket No. 50-247, March 30, 1973.

Lawler, J.P. 1976. Physical measurements - their significance in the prediction of entrainment effects. Presented at the 3rd National Workshop on Entrainment and Impingement, Feb. 2-4 1976.

Lawler, Matusky & Skelly Engineers. 1974. 1973 Hudson River aquatic ecology studies - Bowline Point and Lovett Generating Stations. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers. 1975a. Hudson River study: aquatic factors governing the siting of power plants. Prepared for Empire State Electric Energy Research Corp. [4 vols.]

Lawler, Matusky & Skelly Engineers. 1975b. Thermal surveys at the Bowline Point and Lovett Generating Stations. [August] Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers. 1975c. Thermal surveys of the Bowline Point and Lovett Generating Stations. [October] Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers. 1975d. 1974 Hudson River aquatic ecology studies - Bowline Point and Lovett Generating Stations. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers. 1976a. Bowline and Lovett April and June thermal survey compliance. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers. 1976b. 1975 Hudson River aquatic ecology studies - Bowline Point and Lovett Generating Stations. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers. 1976c. Hudson River ambient temperature survey August-September 1975. Prepared for Central Hudson Gas & Electric Corp., Orange & Rockland Utilities, Inc., Niagara Mohawk Power Corp. and Consolidated Edison Co. of New York, Inc.

REFERENCES CITED (CONT)

Orange and Rockland Utilities, Inc. 1977. Bowline Point Generating Station: Near-field effects of once-through cooling system operation on Hudson River biota.

Parkinson, F.E. 1976. Cornwall pumped storage scheme hydraulic model study of Hudson River flows around screen structures. LaSalle Hydraulic Lab. Prepared for Consolidated Edison Co. of New York, Inc.

Pease, T.E., and M.J. Skelly. 1976. Hydraulic model simulation of winter and summer thermal plumes, Paper given at American Geophysical Union. Oct, 1976.

Quirk, Lawler & Matusky Engineers. 1969. Effect of submerged discharge of Indian Point cooling water on Hudson River temeprature distribution. Report to Consolidated Edison Company of New York, Inc.

Quirk, Lawler, & Matusky Engineers and Oceanographic Analysts, Inc. 1971. Environmental effects of Bowline Point Generating Station on Hudson River: Ecological studies related to the proposed generating station at Bowline Point, N.Y. Prepared for Orange and Rockland Utilities, Inc. and Consolidated Edison Company of New York, Inc.

Robideau, R.F. 1972. The discharge of submerged buoyant jets into water of finite depth. General Dynamics Electric Boat Div. [Groton, Conn.] U440-72-121: 860p. [PB 214-475].

U.S. Coast & Geodetic Survey. 1968. Surface water temperature and density - Atlantic Coast, North and South America. 3rd ed. USC&GS Publ. 31-1.

U.S. Environmental Protection Agency (EPA). 1974. 316(a) Technical guidance - thermal discharges. [Draft Report] Water Planning Division, Office of Water and Hazardous Materials, EPA. 188p.

U.S. Geological Survey. 1965. Water resources data for New York. II. Water quality records. 1964-1965. U.S. Dept. of Interior, Washington, D.C.

APPENDIX

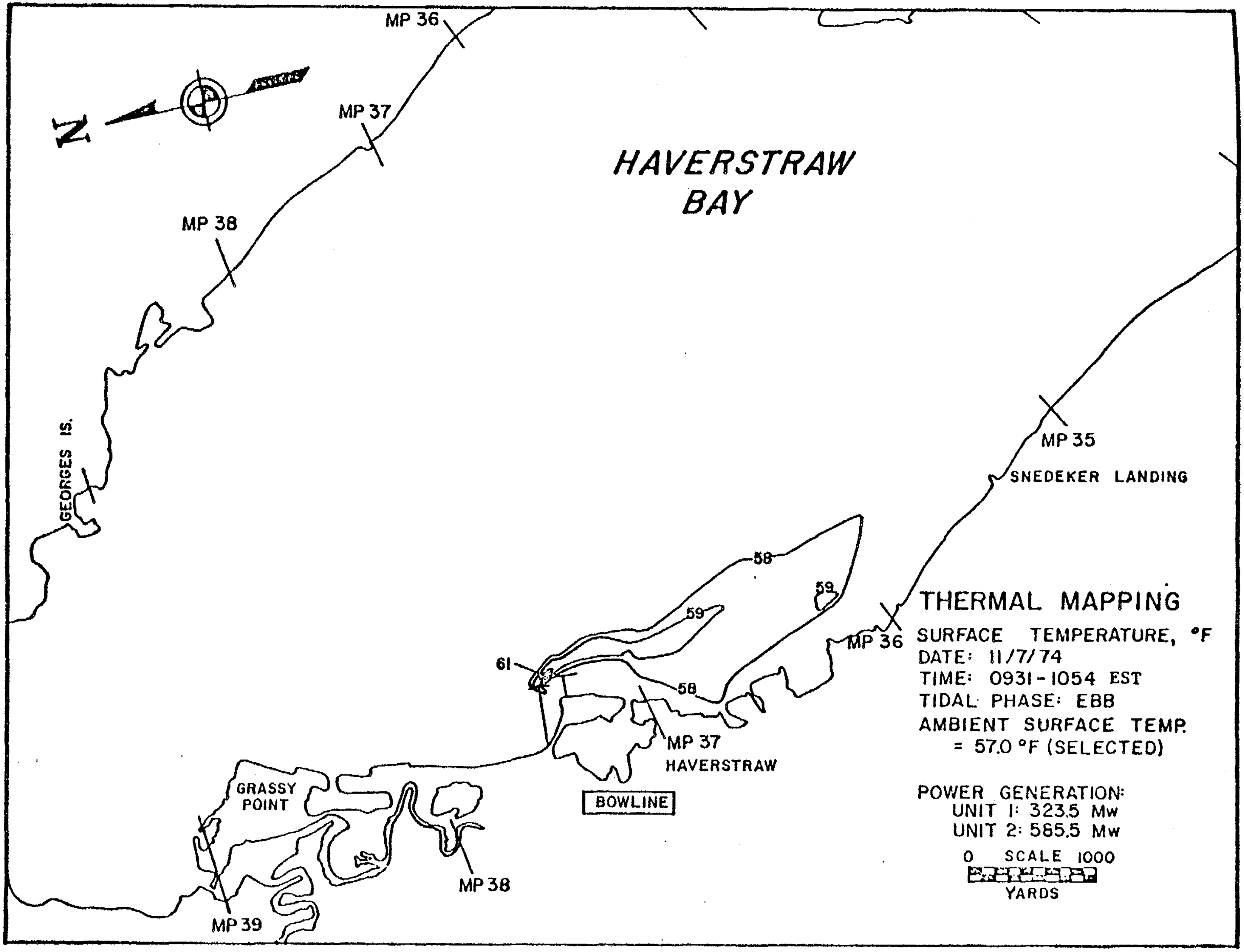

N
MP 36
MP 37
MP 38
HAVERSTRAW BAY
GEORGES IS.
MP 35
SNEDEKER LANDING
58
59
59
61
58
MP 36
MP 37
HAVERSTRAW
BOWLINE
GRASSY POINT
MP 38
MP 39
THERMAL MAPPING
SURFACE TEMPERATURE, °F
DATE: 11/7/74
TIME: 0931-1054 EST
TIDAL PHASE: EBB
AMBIENT SURFACE TEMP. = 57.0 °F (SELECTED)
POWER GENERATION:
UNIT 1: 323.5 Mw
UNIT 2: 585.5 Mw
0 SCALE 1000
YARDS

FIGURE A-1

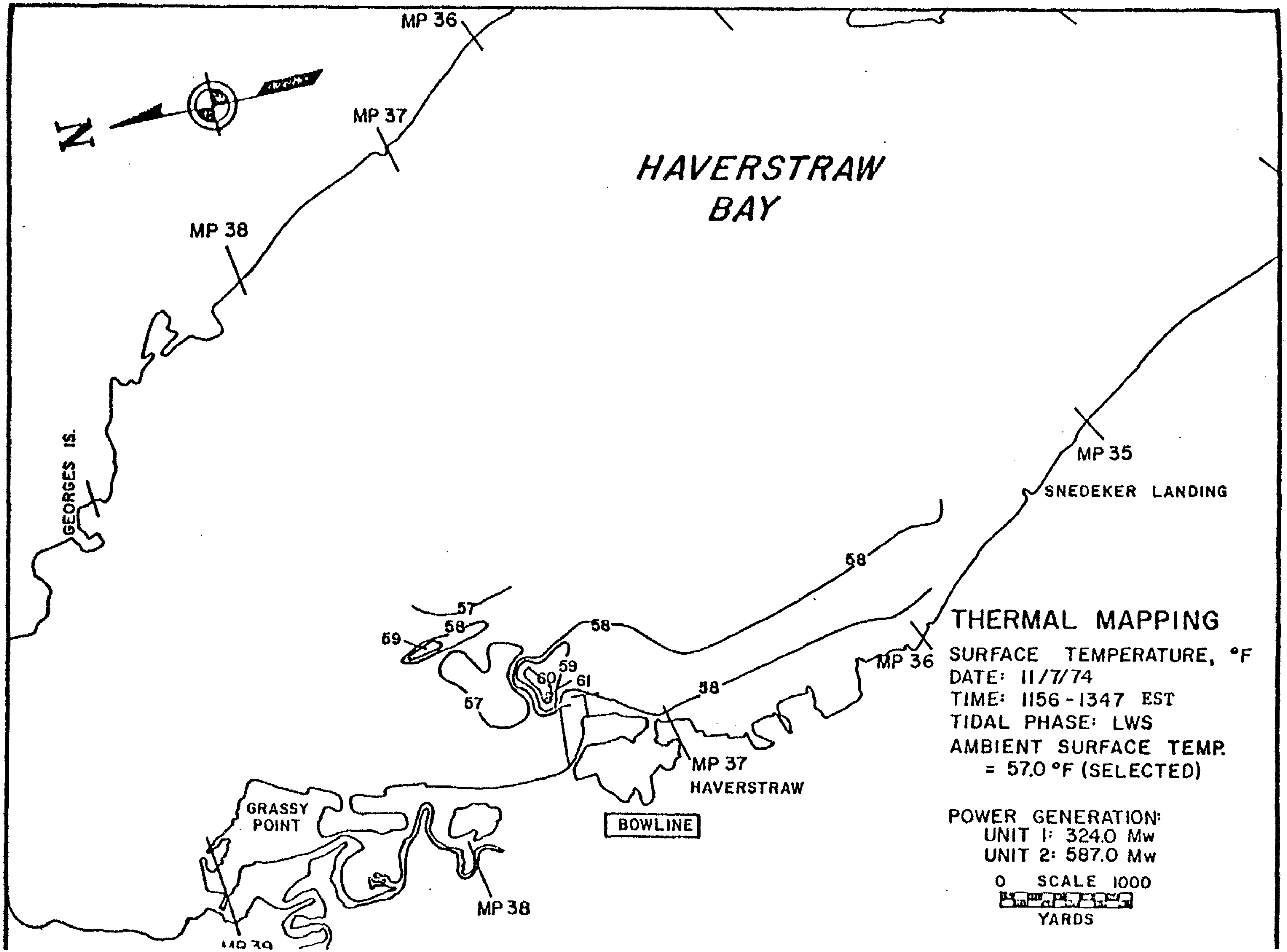
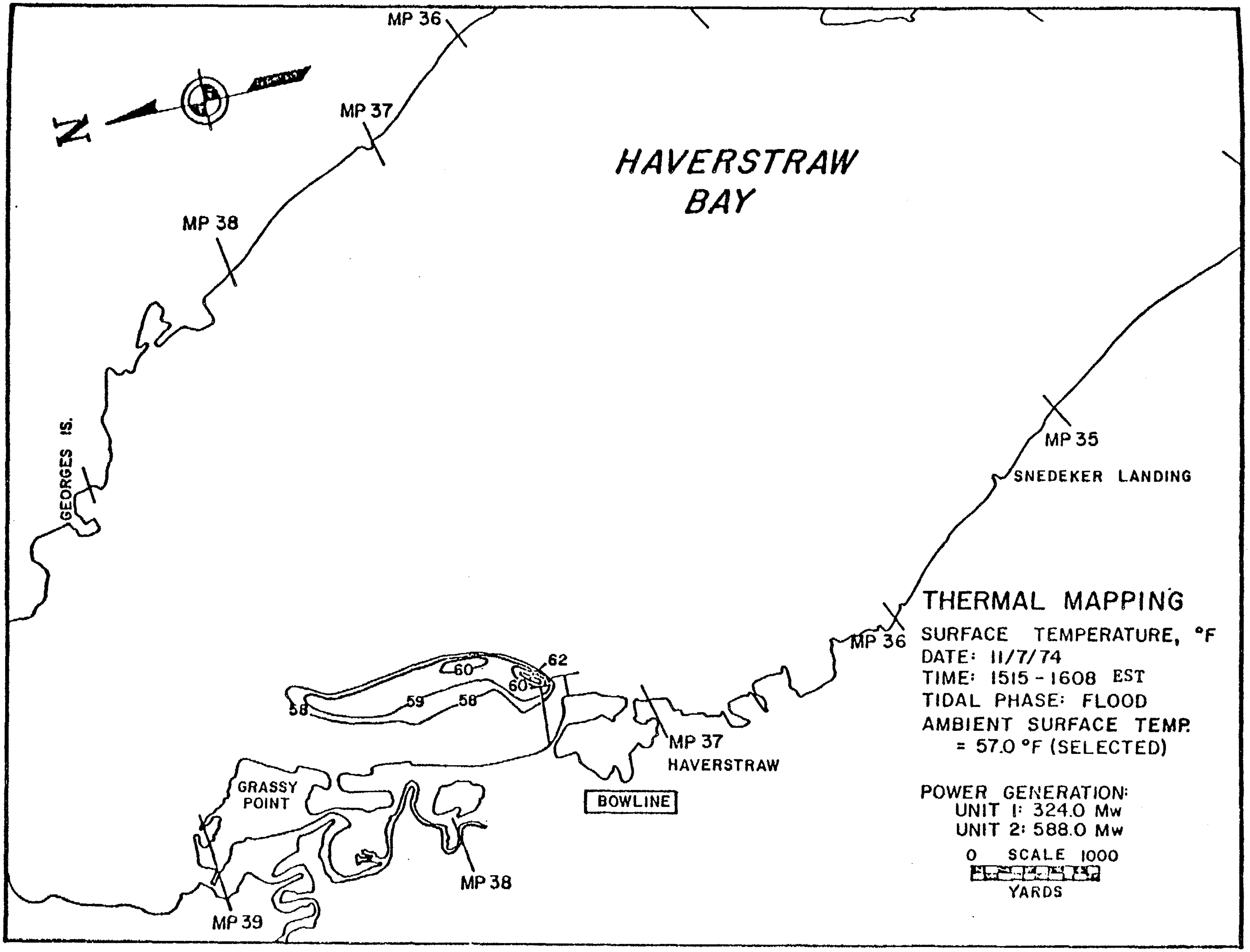

N
MP 36
MP 37
MP 38
HAVERSTRAW BAY
GEORGES IS.
MP 35
SNEDEKER LANDING
58
57
58
69
58
59
60
61
57
58
MP 36
MP 37
HAVERSTRAW
BOWLINE
GRASSY POINT
MP 38
MP 39
THERMAL MAPPING
SURFACE TEMPERATURE, °F
DATE: 11/7/74
TIME: 1156-1347 EST
TIDAL PHASE: LWS
AMBIENT SURFACE TEMP. = 57.0 °F (SELECTED)
POWER GENERATION:
UNIT 1: 324.0 Mw
UNIT 2: 587.0 Mw
0 SCALE 1000
YARDS

FIGURE A-2

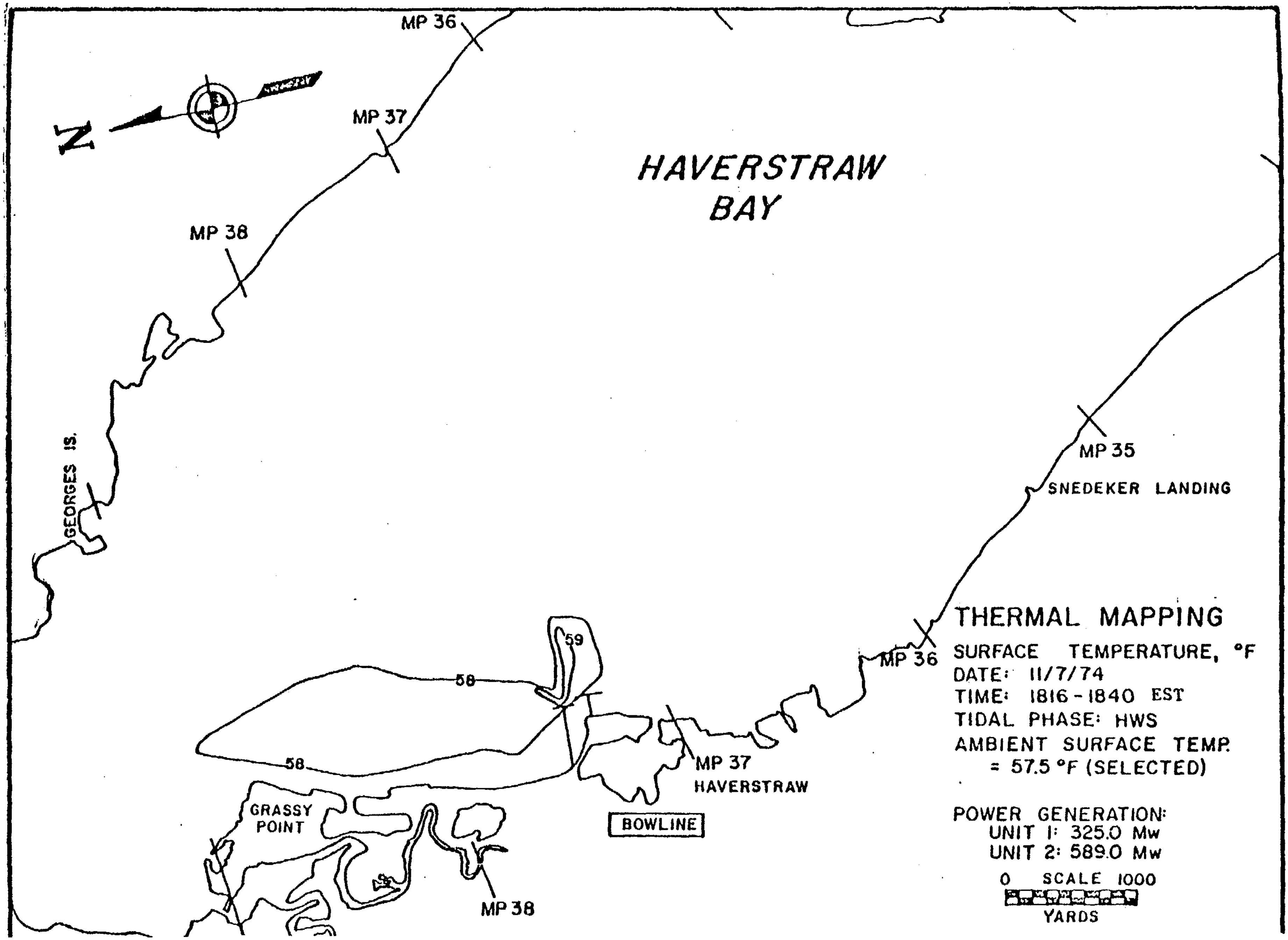


THERMAL MAPPING

SURFACE TEMPERATURE, °F
DATE: 11/7/74
TIME: 1515 - 1608 EST
TIDAL PHASE: FLOOD
AMBIENT SURFACE TEMP. = 57.0 °F (SELECTED)

POWER GENERATION:
UNIT 1: 324.0 Mw
UNIT 2: 588.0 Mw

FIGURE A-3



THERMAL MAPPING

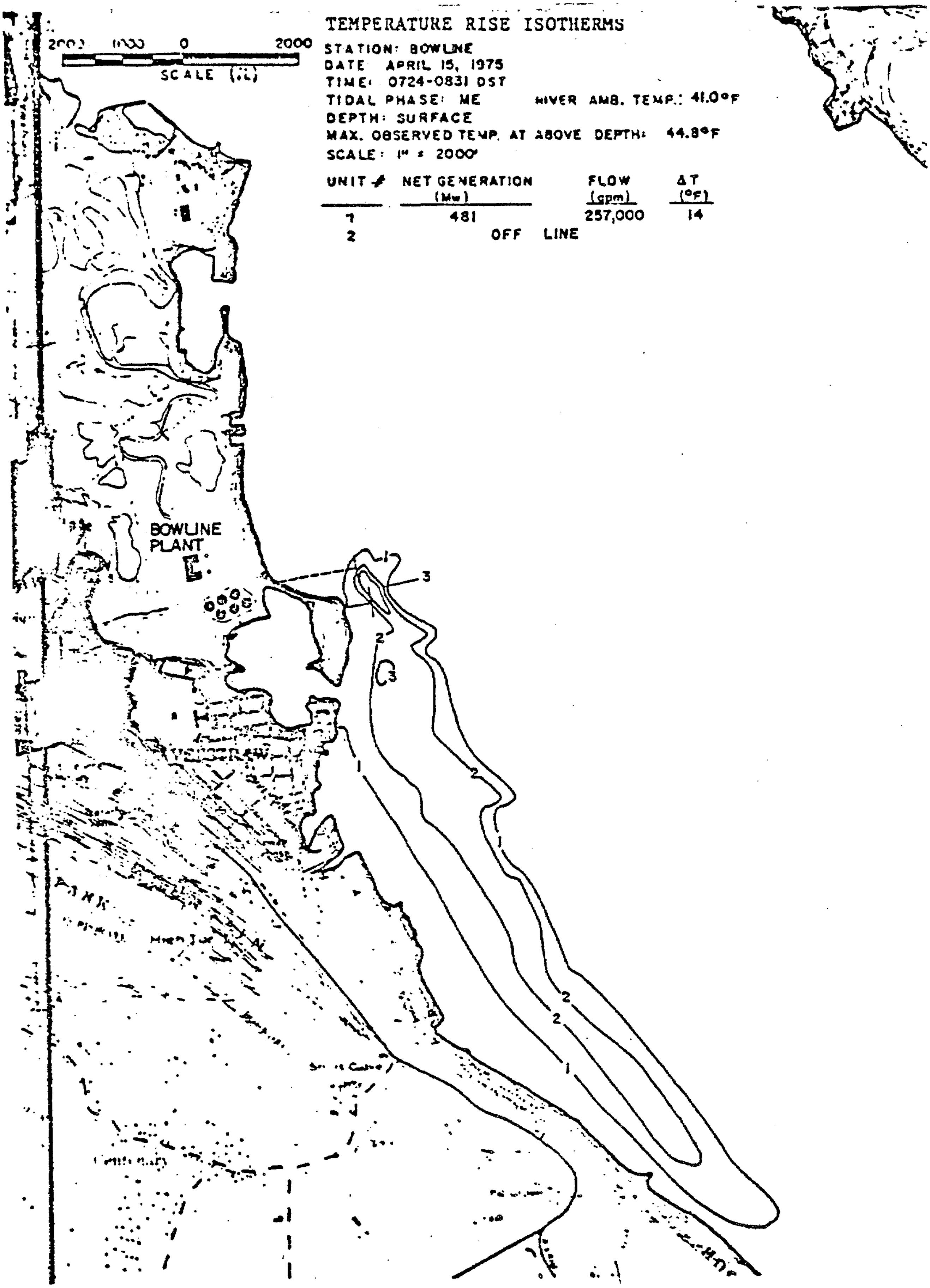
SURFACE TEMPERATURE, °F
DATE: 11/7/74
TIME: 1816 - 1840 EST
TIDAL PHASE: HWS
AMBIENT SURFACE TEMP. = 57.5 °F (SELECTED)

POWER GENERATION:
UNIT 1: 325.0 Mw
UNIT 2: 589.0 Mw

0 SCALE 1000 YARDS

FIGURE A-4

FIGURE A-5

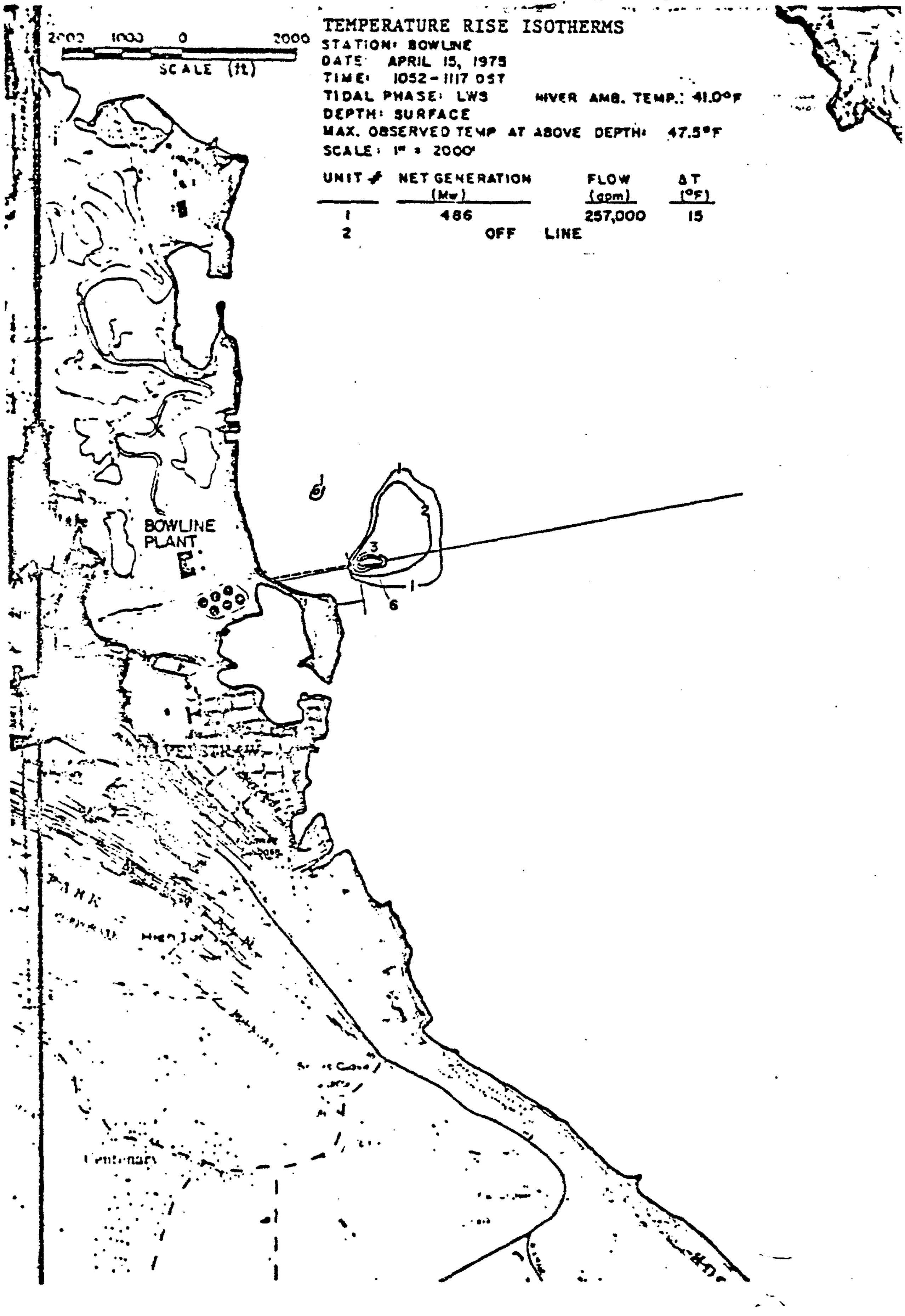


TEMPERATURE RISE ISOTHERMS

STATION: BOWLINE
DATE APRIL 15, 1975
TIME: 0724-0831 DST
TIDAL PHASE: ME RIVER AMB. TEMP.: 41.0°F
DEPTH: SURFACE
MAX. OBSERVED TEMP. AT ABOVE DEPTH: 44.8°F
SCALE: 1" = 2000'

UNIT #	NET GENERATION (Mw)	FLOW (gpm)	ΔT (°F)
1	481	257,000	14
2	OFF LINE		

FIGURE A-6

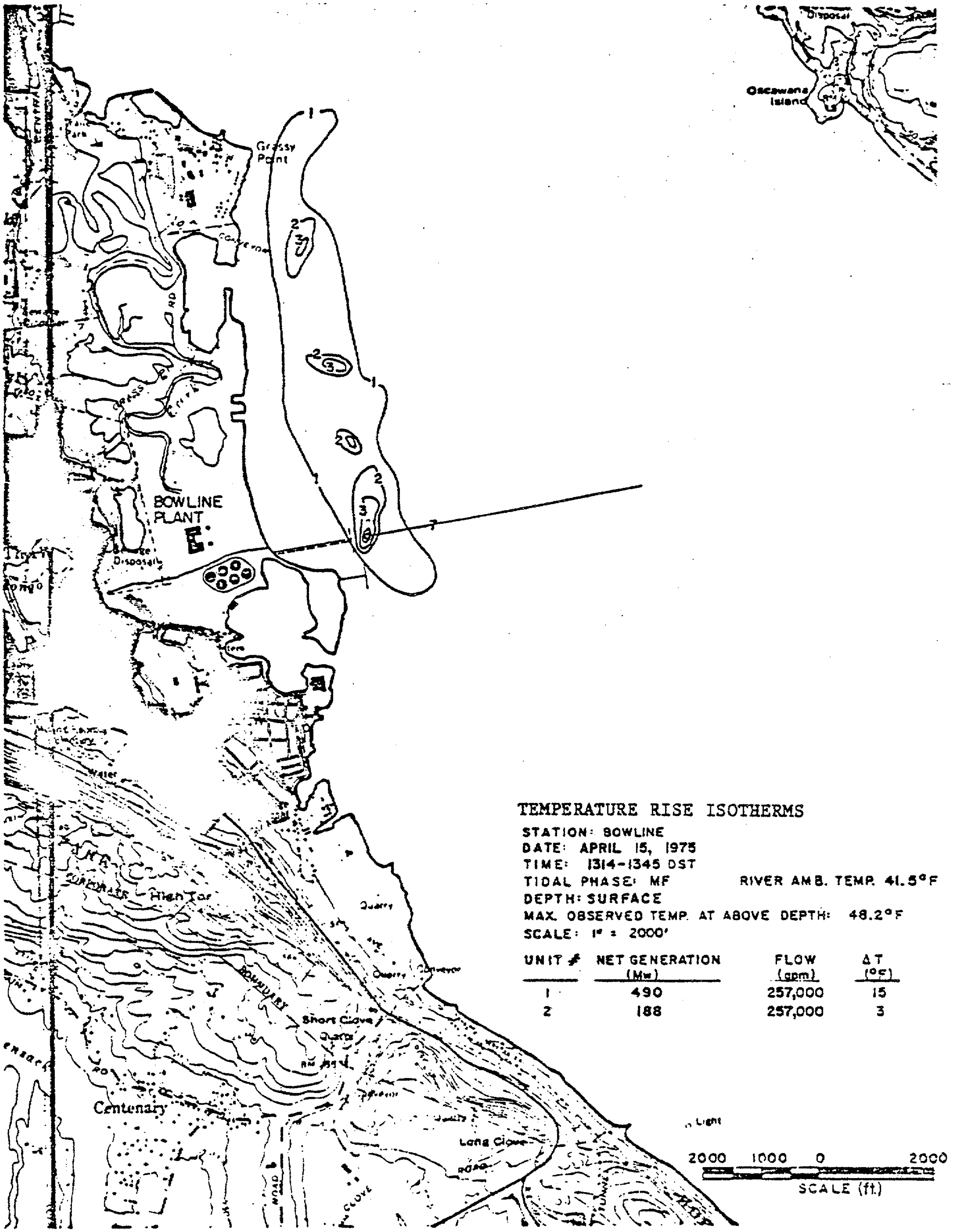


TEMPERATURE RISE ISOTHERMS

STATION: BOWLINE
DATE: APRIL 15, 1975
TIME: 1052-1117 DST
TIDAL PHASE: LWS RIVER AMB. TEMP.: 41.0°F
DEPTH: SURFACE
MAX. OBSERVED TEMP AT ABOVE DEPTH: 47.5°F
SCALE: 1" = 2000'

UNIT #	NET GENERATION (Mw)	FLOW (gpm)	ΔT (°F)
1	486	257,000	15
2	OFF LINE		

FIGURE A-7

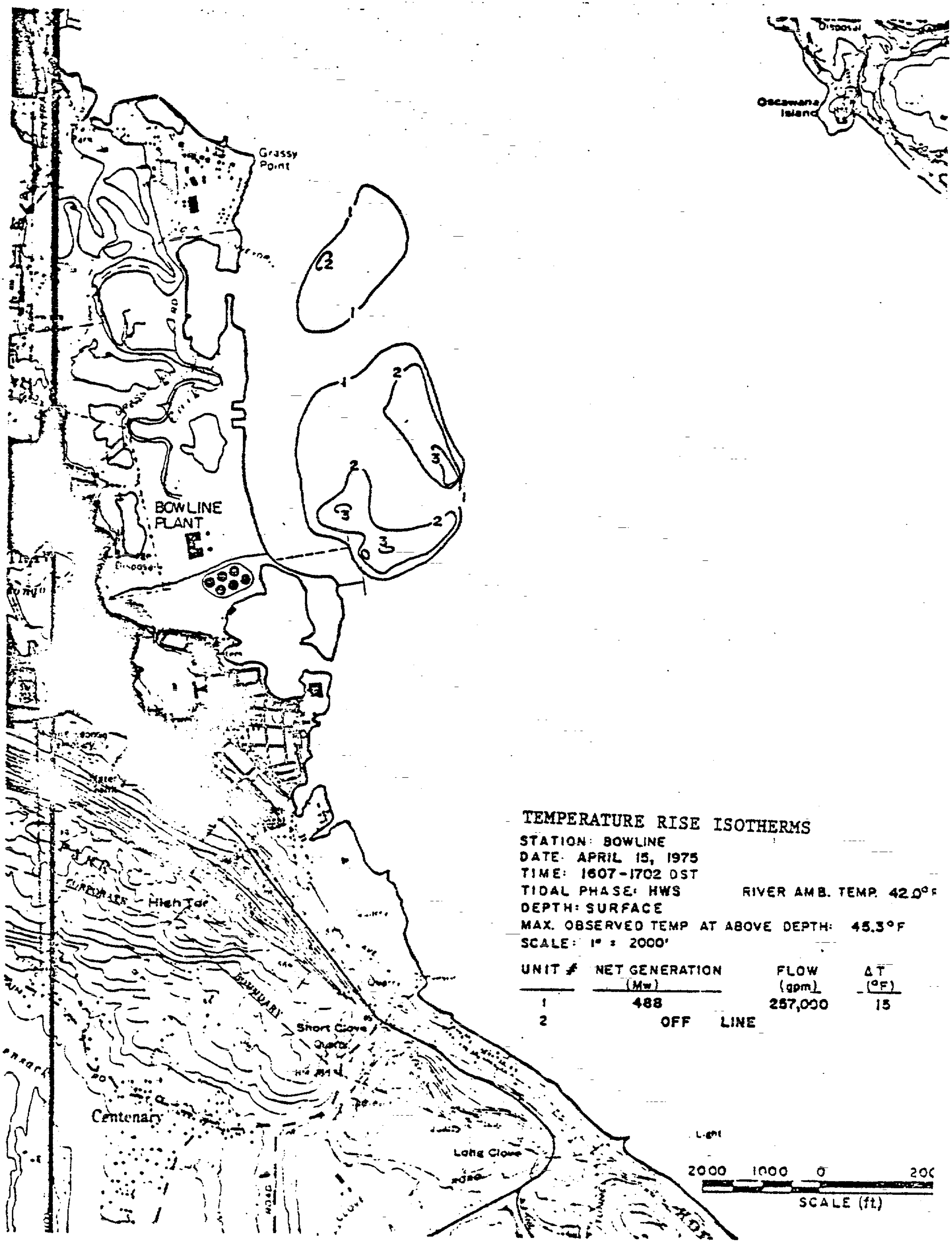


TEMPERATURE RISE ISOTHERMS

STATION: BOWLINE
DATE: APRIL 15, 1975
TIME: 1314-1345 DST
TIDAL PHASE: MF
RIVER AMB. TEMP. 41.5°F
DEPTH: SURFACE
MAX. OBSERVED TEMP. AT ABOVE DEPTH: 48.2°F
SCALE: 1" = 2000'

UNIT #	NET GENERATION (Mw)	FLOW (gpm)	ΔT (°F)
1	490	257,000	15
2	188	257,000	3

FIGURE A-8

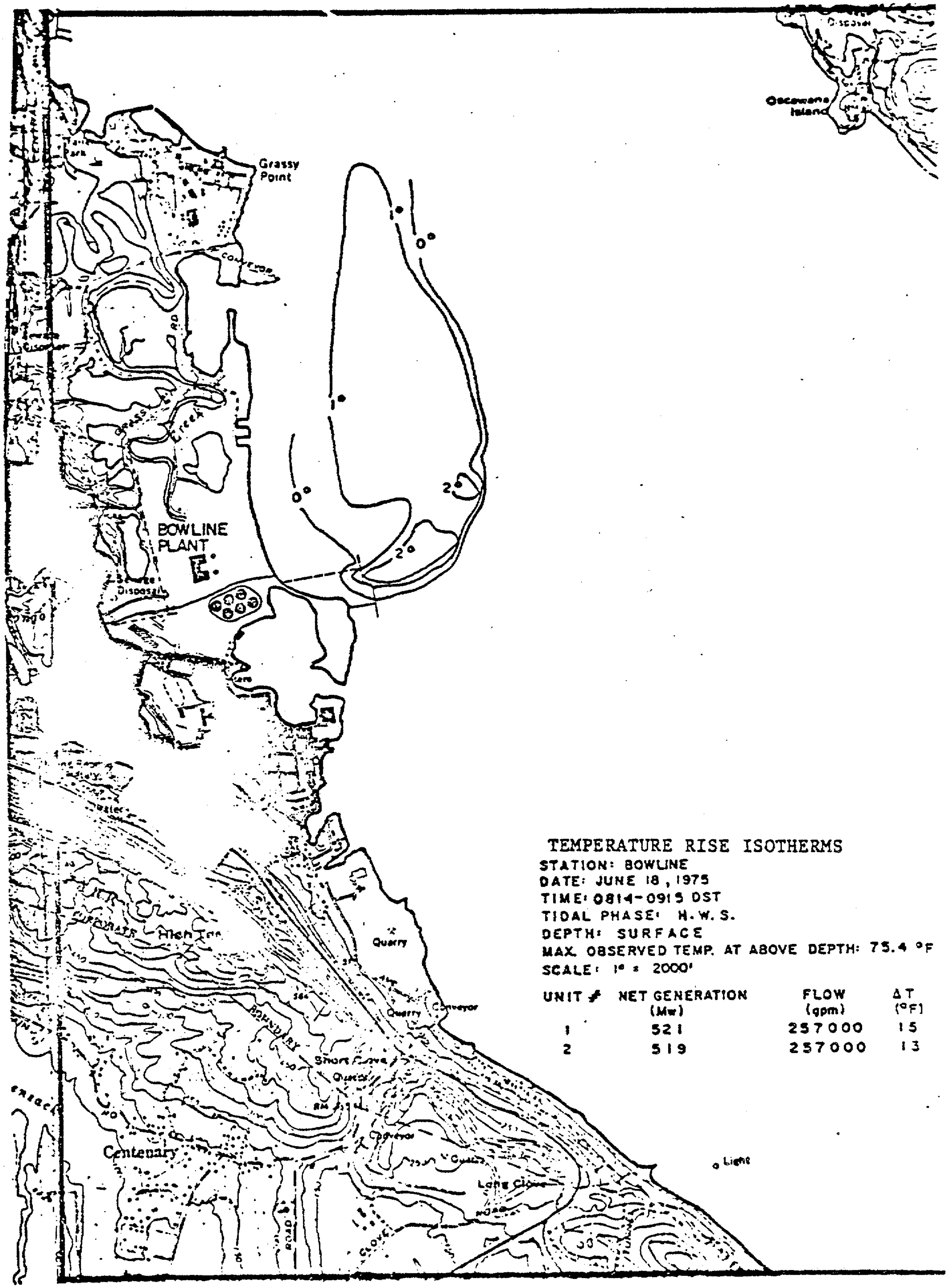


TEMPERATURE RISE ISOTHERMS

STATION: BOWLINE
DATE: APRIL 15, 1975
TIME: 1607-1702 DST
TIDAL PHASE: HWS RIVER AMB. TEMP. 42.0°F
DEPTH: SURFACE
MAX. OBSERVED TEMP AT ABOVE DEPTH: 45.3°F
SCALE: 1" = 2000'

UNIT #	NET GENERATION (Mw)	FLOW (gpm)	ΔT (°F)
1	488	257,000	15
2	OFF	LINE	

FIGURE A-9

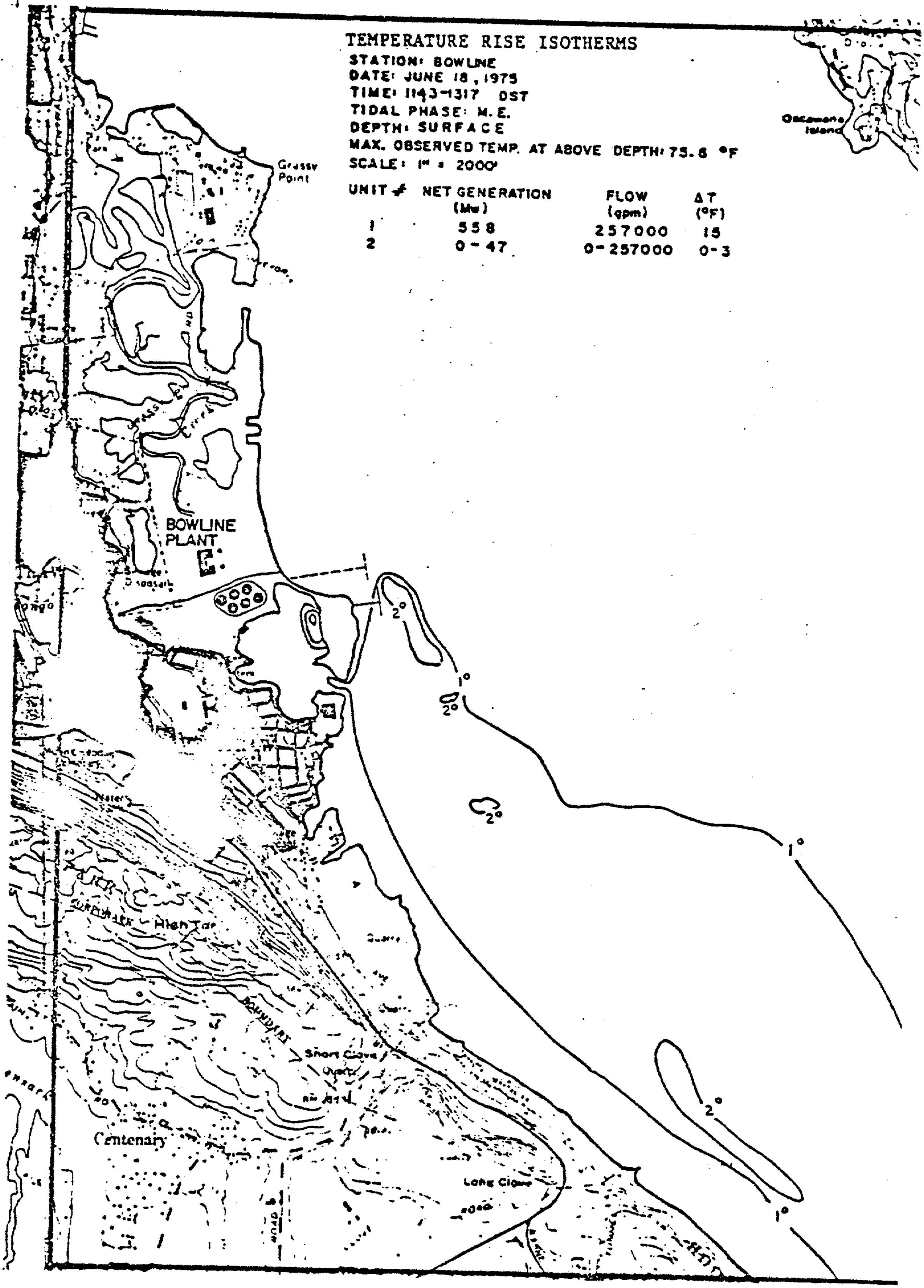


TEMPERATURE RISE ISOTHERMS

STATION: BOWLINE
DATE: JUNE 18, 1975
TIME: 0814-0915 DST
TIDAL PHASE: H.W.S.
DEPTH: SURFACE
MAX. OBSERVED TEMP. AT ABOVE DEPTH: 75.4 °F
SCALE: 1" = 2000'

UNIT #	NET GENERATION (Mw)	FLOW (gpm)	ΔT (°F)
1	521	257000	15
2	519	257000	13

FIGURE A-10

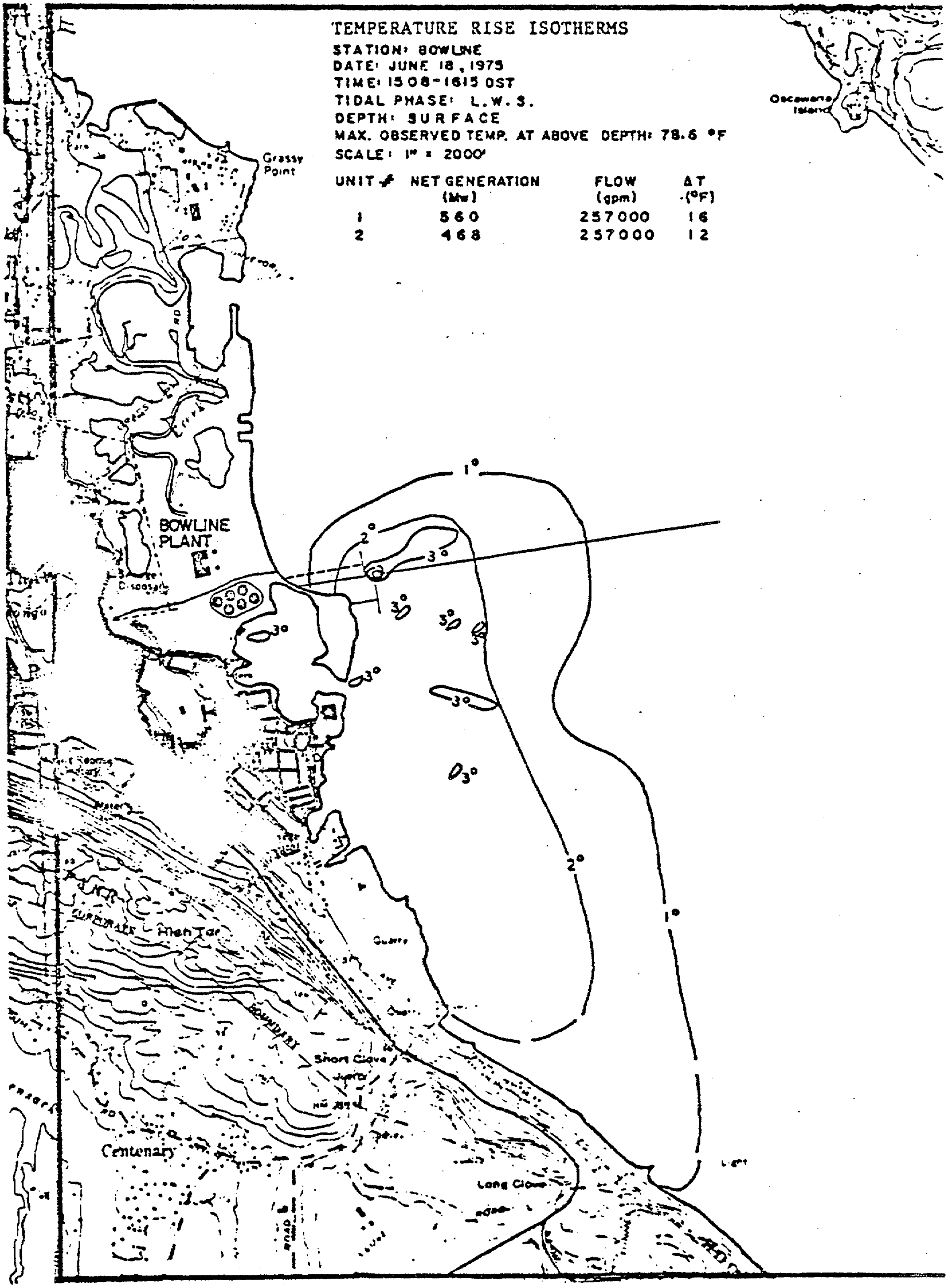


TEMPERATURE RISE ISOTHERMS

STATION: BOWLINE
DATE: JUNE 18, 1975
TIME: 1143-1317 DST
TIDAL PHASE: M.E.
DEPTH: SURFACE
MAX. OBSERVED TEMP. AT ABOVE DEPTH: 75.6 °F
SCALE: 1" = 2000'

UNIT #	NET GENERATION (Mw)	FLOW (gpm)	ΔT (°F)
1	558	257000	15
2	0 - 47	0-257000	0-3

FIGURE A-11

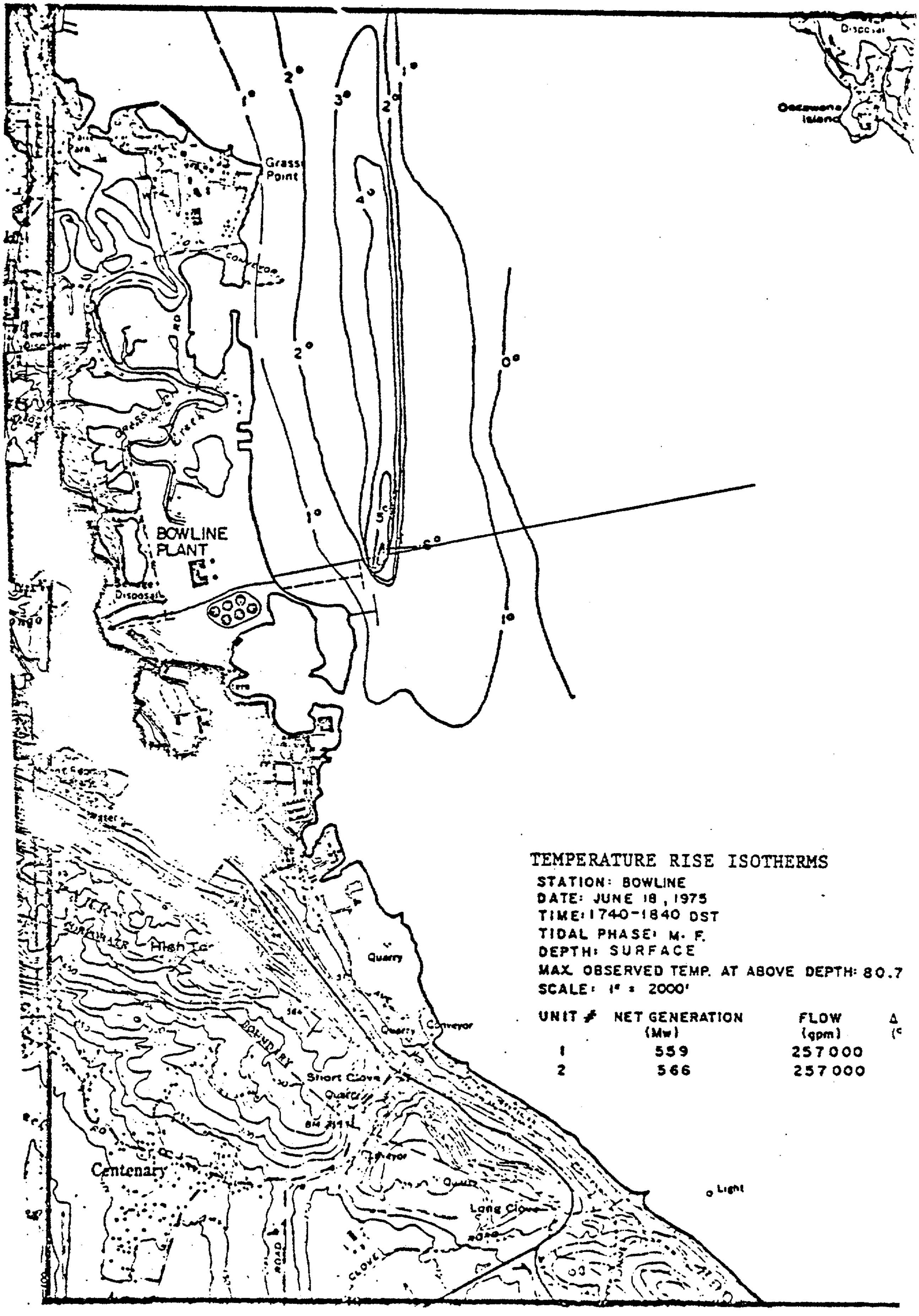


TEMPERATURE RISE ISOTHERMS

STATION: BOWLINE
DATE: JUNE 18, 1975
TIME: 1508-1615 DST
TIDAL PHASE: L.W.S.
DEPTH: SURFACE
MAX. OBSERVED TEMP. AT ABOVE DEPTH: 78.6 °F
SCALE: 1" = 2000'

UNIT #	NET GENERATION (Mw)	FLOW (gpm)	ΔT (°F)
1	560	257000	16
2	468	257000	12

FIGURE A-12

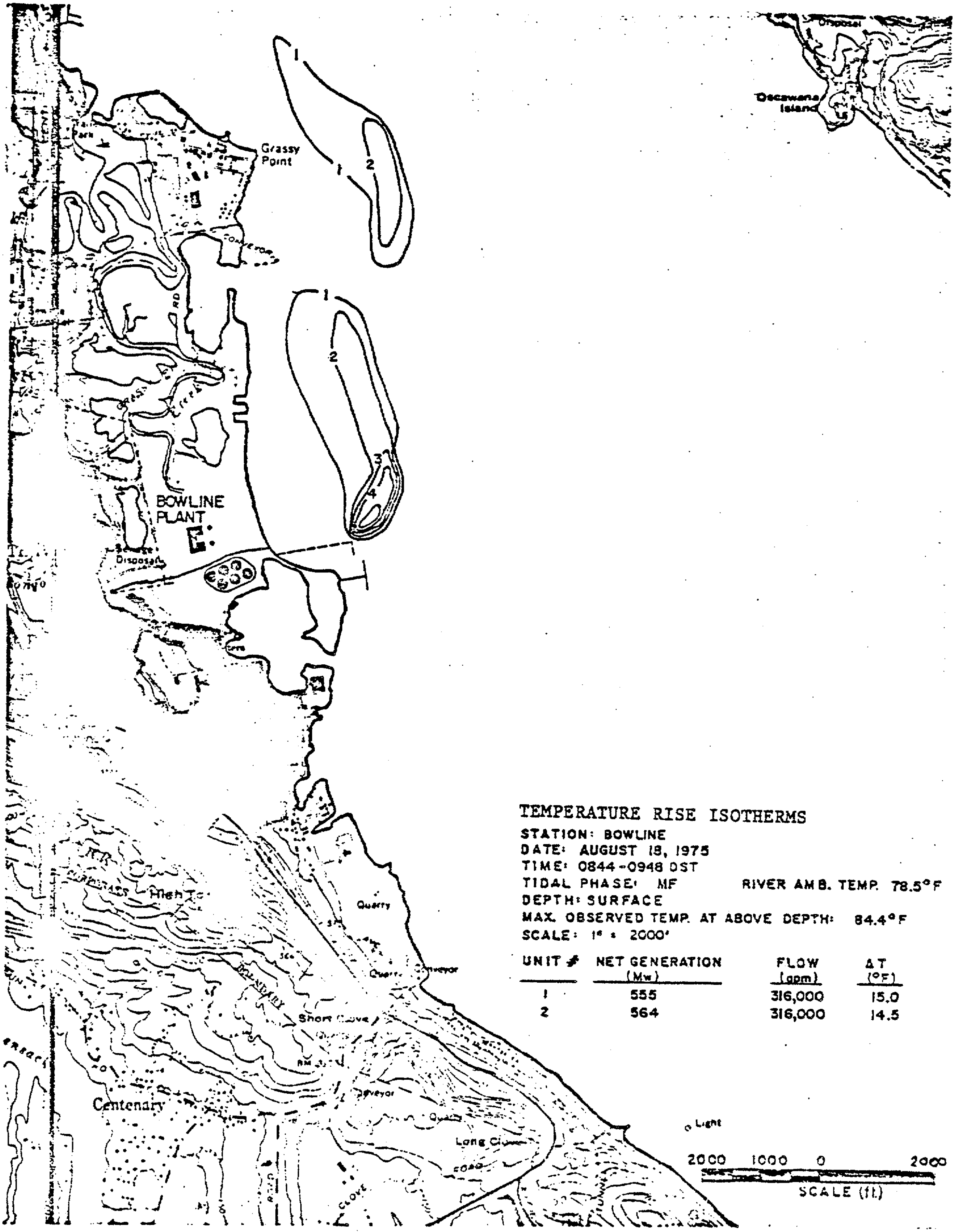


TEMPERATURE RISE ISOTHERMS

STATION: BOWLINE
DATE: JUNE 18, 1975
TIME: 1740-1840 DST
TIDAL PHASE: M. F.
DEPTH: SURFACE
MAX. OBSERVED TEMP. AT ABOVE DEPTH: 80.7
SCALE: 1" = 2000'

UNIT #	NET GENERATION (Mw)	FLOW (gpm)	Δ (°
1	559	257000	
2	566	257000	

FIGURE A-13

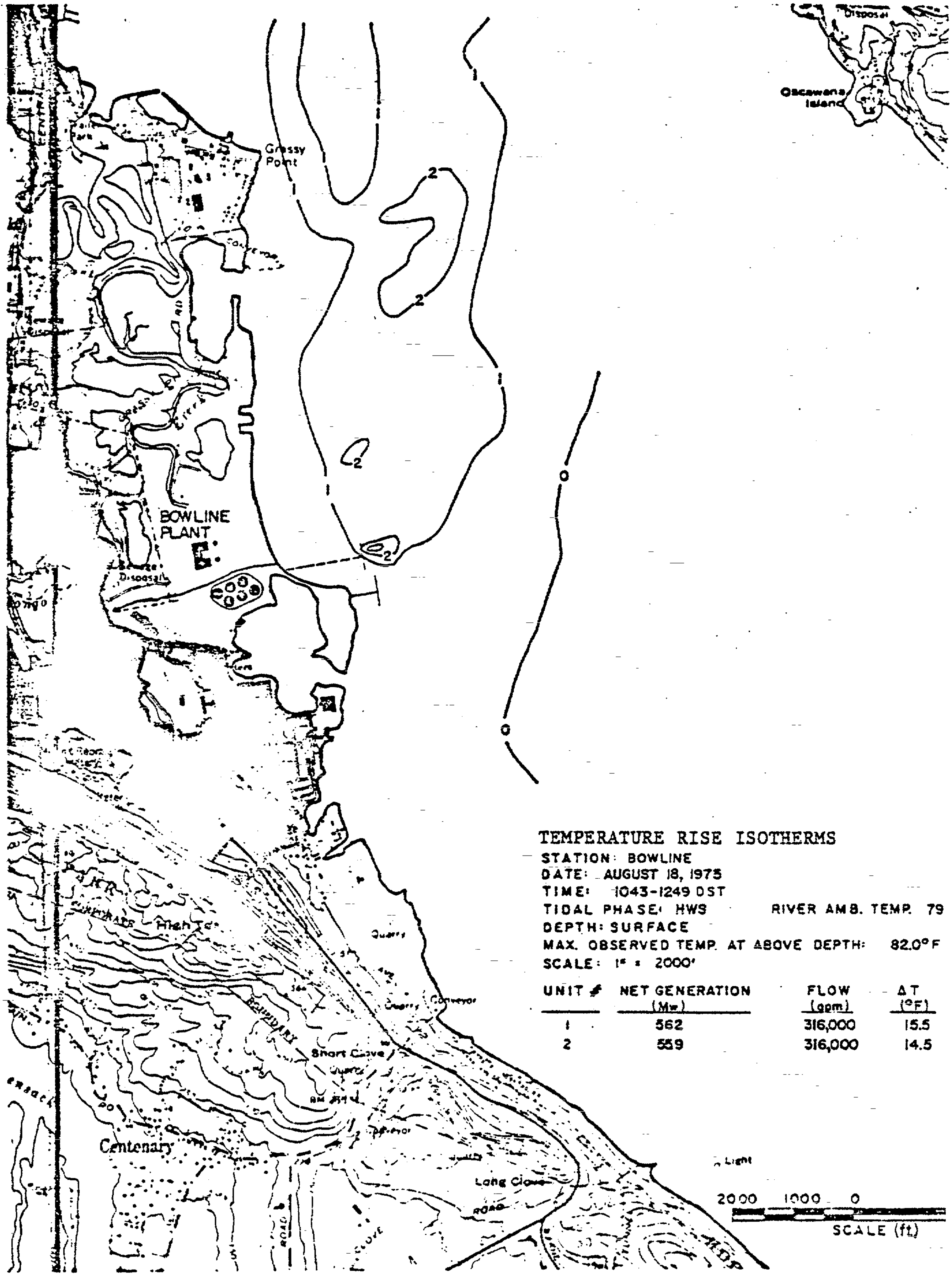


TEMPERATURE RISE ISOTHERMS

STATION: BOWLINE
DATE: AUGUST 18, 1975
TIME: 0844-0948 DST
TIDAL PHASE: MF RIVER AMB. TEMP. 78.5°F
DEPTH: SURFACE
MAX. OBSERVED TEMP. AT ABOVE DEPTH: 84.4°F
SCALE: 1" = 2000'

UNIT #	NET GENERATION (Mw)	FLOW (gpm)	ΔT (°F)
1	555	316,000	15.0
2	564	316,000	14.5

FIGURE A-14

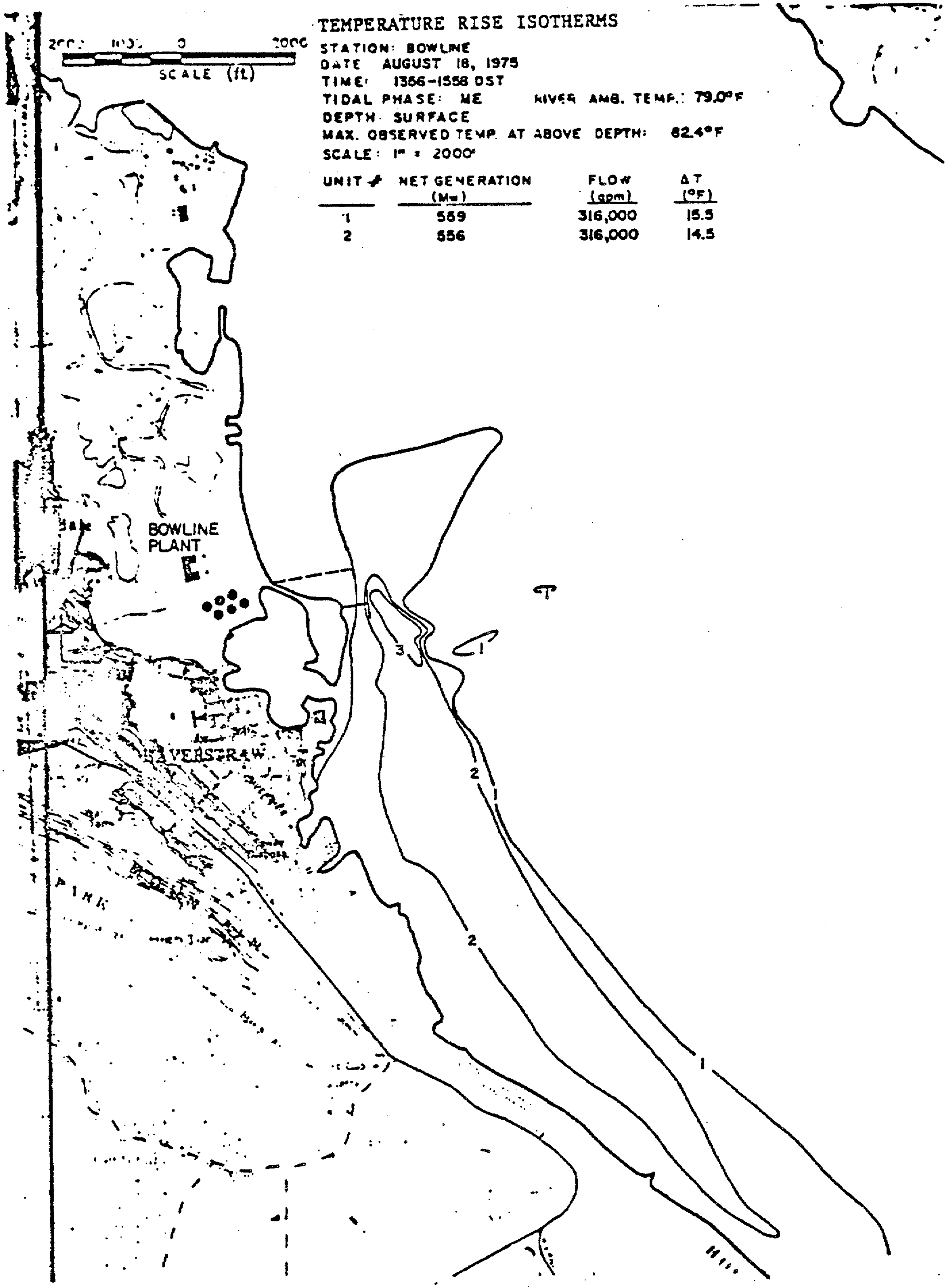


TEMPERATURE RISE ISOTHERMS

STATION: BOWLINE
DATE: AUGUST 18, 1975
TIME: 1043-1249 DST
TIDAL PHASE: HWS RIVER AMB. TEMP. 79
DEPTH: SURFACE
MAX. OBSERVED TEMP. AT ABOVE DEPTH: 82.0°F
SCALE: 1" = 2000'

UNIT #	NET GENERATION (Mw)	FLOW (gpm)	ΔT (°F)
1	562	316,000	15.5
2	559	316,000	14.5

FIGURE A-15

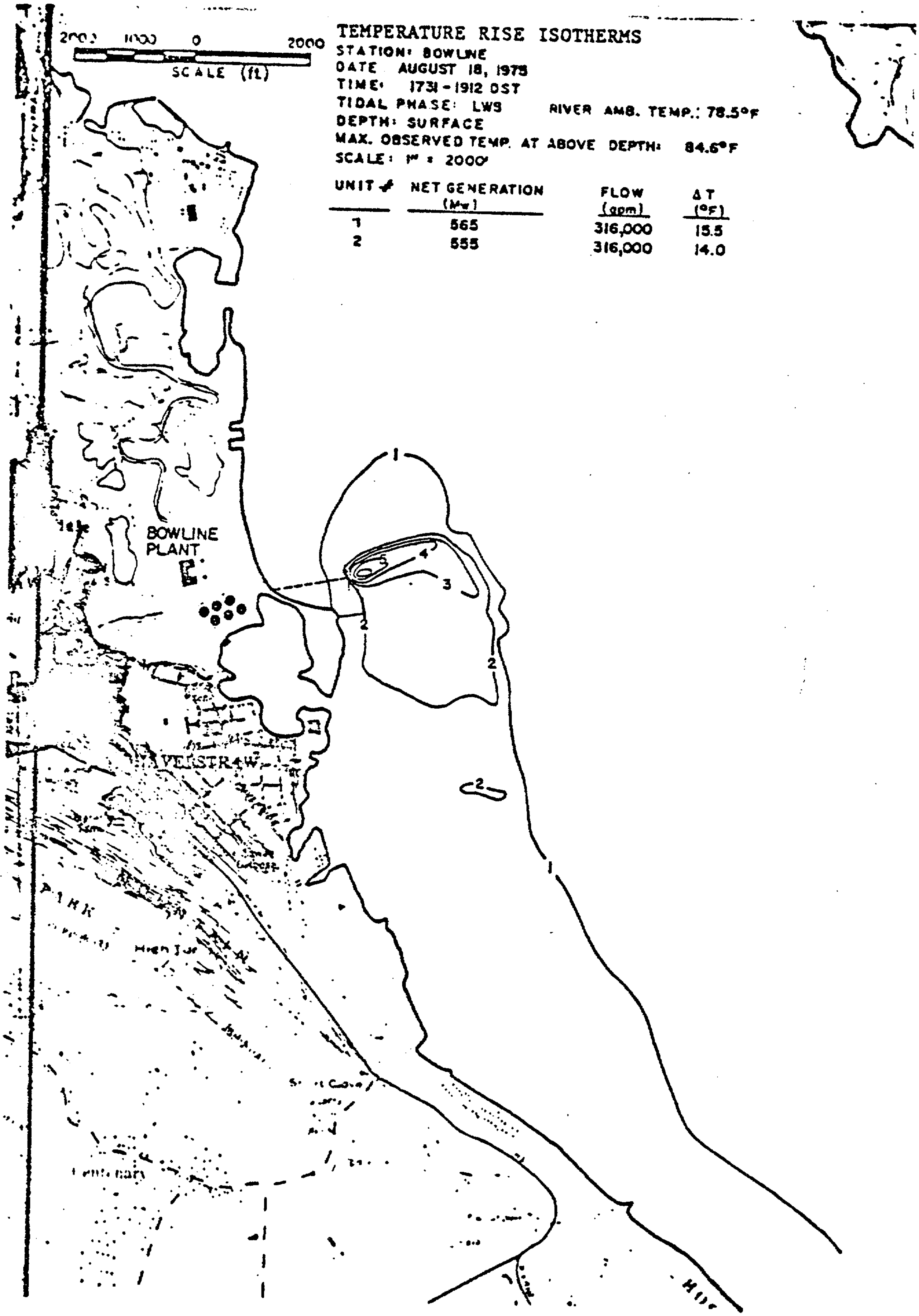


TEMPERATURE RISE ISOTHERMS

STATION: BOWLINE
DATE AUGUST 18, 1975
TIME: 1366-1558 DST
TIDAL PHASE: ME RIVER AMB. TEMP.: 79.0°F
DEPTH: SURFACE
MAX. OBSERVED TEMP. AT ABOVE DEPTH: 82.4°F
SCALE: 1" = 2000'

UNIT #	NET GENERATION (Mw)	FLOW (gpm)	ΔT (°F)
1	569	316,000	15.5
2	556	316,000	14.5

FIGURE A-16

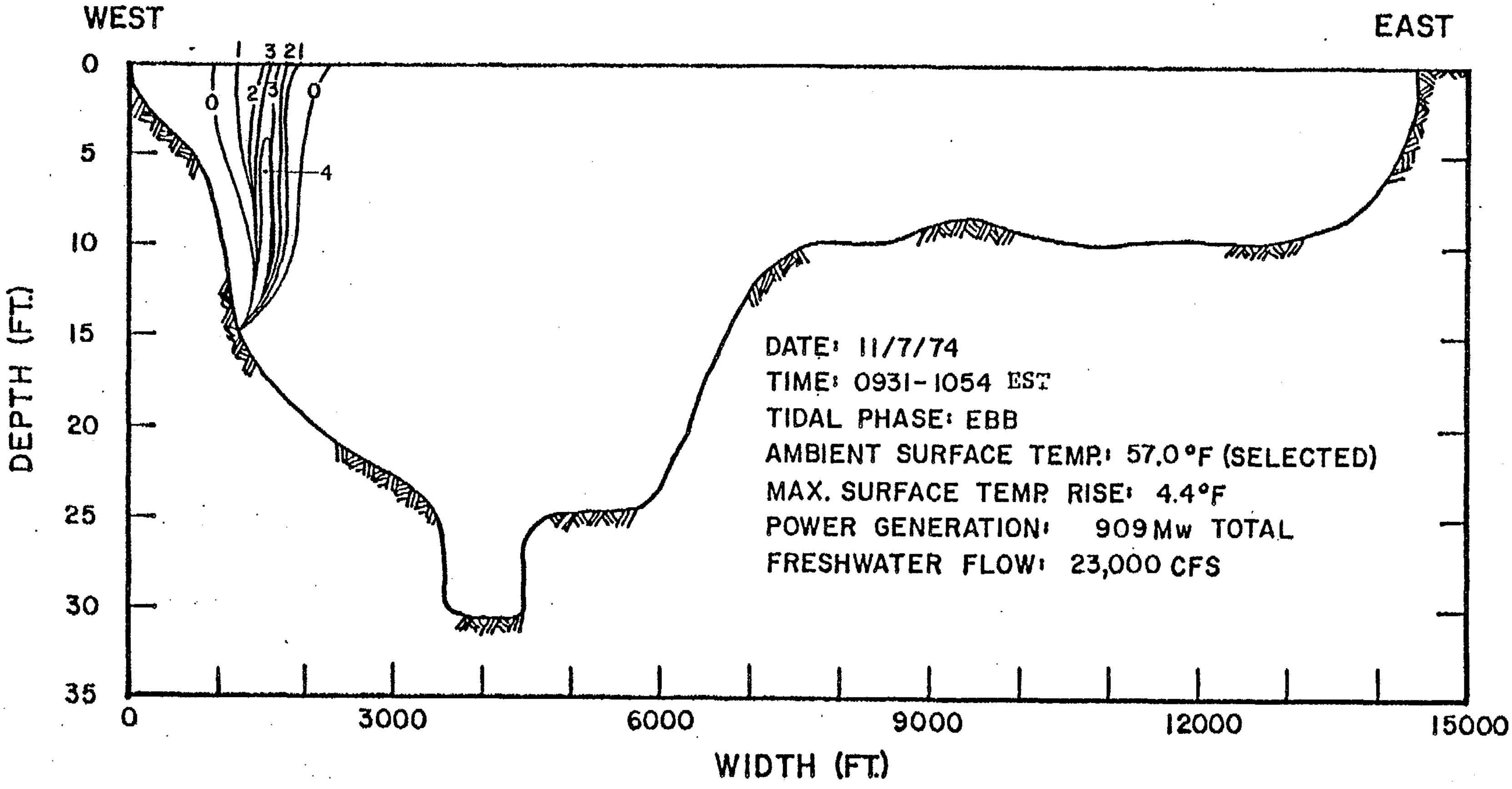


TEMPERATURE RISE ISOTHERMS

STATION: BOWLINE
DATE AUGUST 18, 1975
TIME: 1731 - 1912 DST
TIDAL PHASE: LWS RIVER AMB. TEMP.: 78.5°F
DEPTH: SURFACE
MAX. OBSERVED TEMP. AT ABOVE DEPTH: 84.6°F
SCALE: 1" = 2000'

UNIT #	NET GENERATION (Mw)	FLOW (gpm)	ΔT (°F)
1	565	316,000	15.5
2	555	316,000	14.0

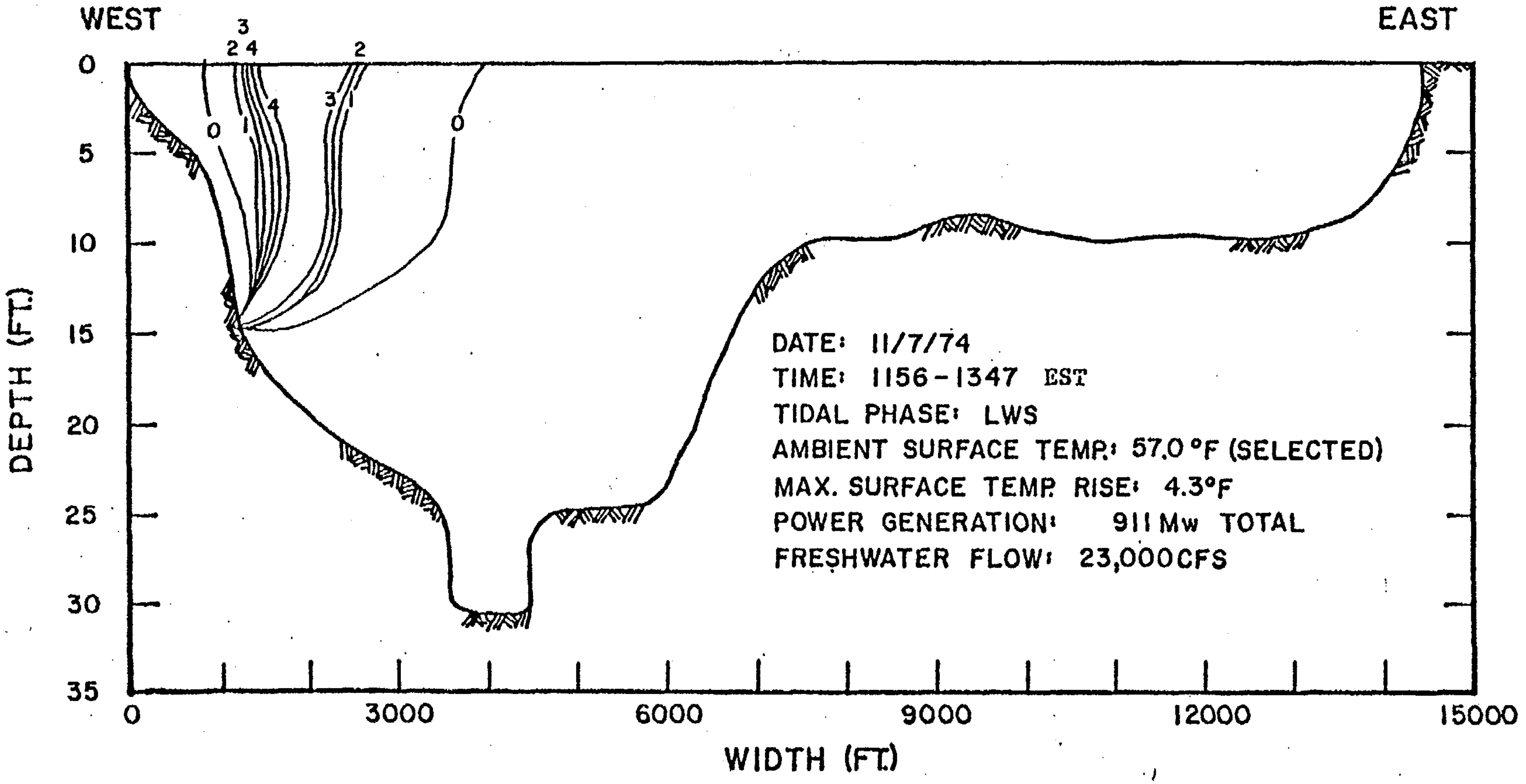
BOWLINE DISCHARGE
CROSS-SECTIONAL TEMPERATURE (°F) DISTRIBUTION
TEMPERATURE RISE ISOTHERMS



DATE: 11/7/74
TIME: 0931-1054 EST
TIDAL PHASE: EBB
AMBIENT SURFACE TEMP.: 57.0 °F (SELECTED)
MAX. SURFACE TEMP. RISE: 4.4°F
POWER GENERATION: 909 Mw TOTAL
FRESHWATER FLOW: 23,000 CFS

FIGURE A-17

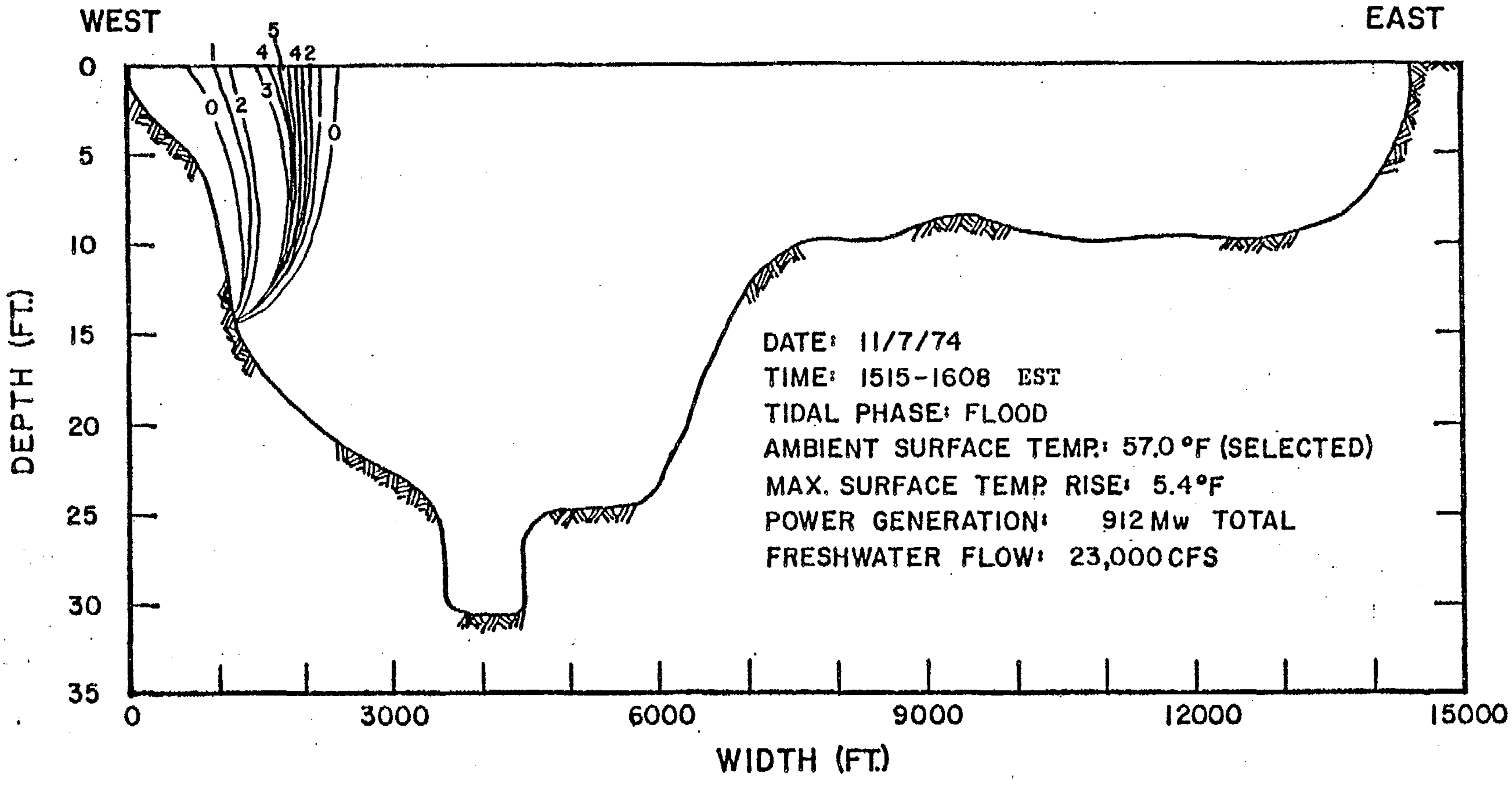
BOWLINE DISCHARGE
CROSS-SECTIONAL TEMPERATURE (°F) DISTRIBUTION
TEMPERATURE RISE ISOTHERMS



DATE: 11/7/74
TIME: 1156-1347 EST
TIDAL PHASE: LWS
AMBIENT SURFACE TEMP: 57.0 °F (SELECTED)
MAX. SURFACE TEMP RISE: 4.3°F
POWER GENERATION: 911 Mw TOTAL
FRESHWATER FLOW: 23,000CFS

FIGURE A-18

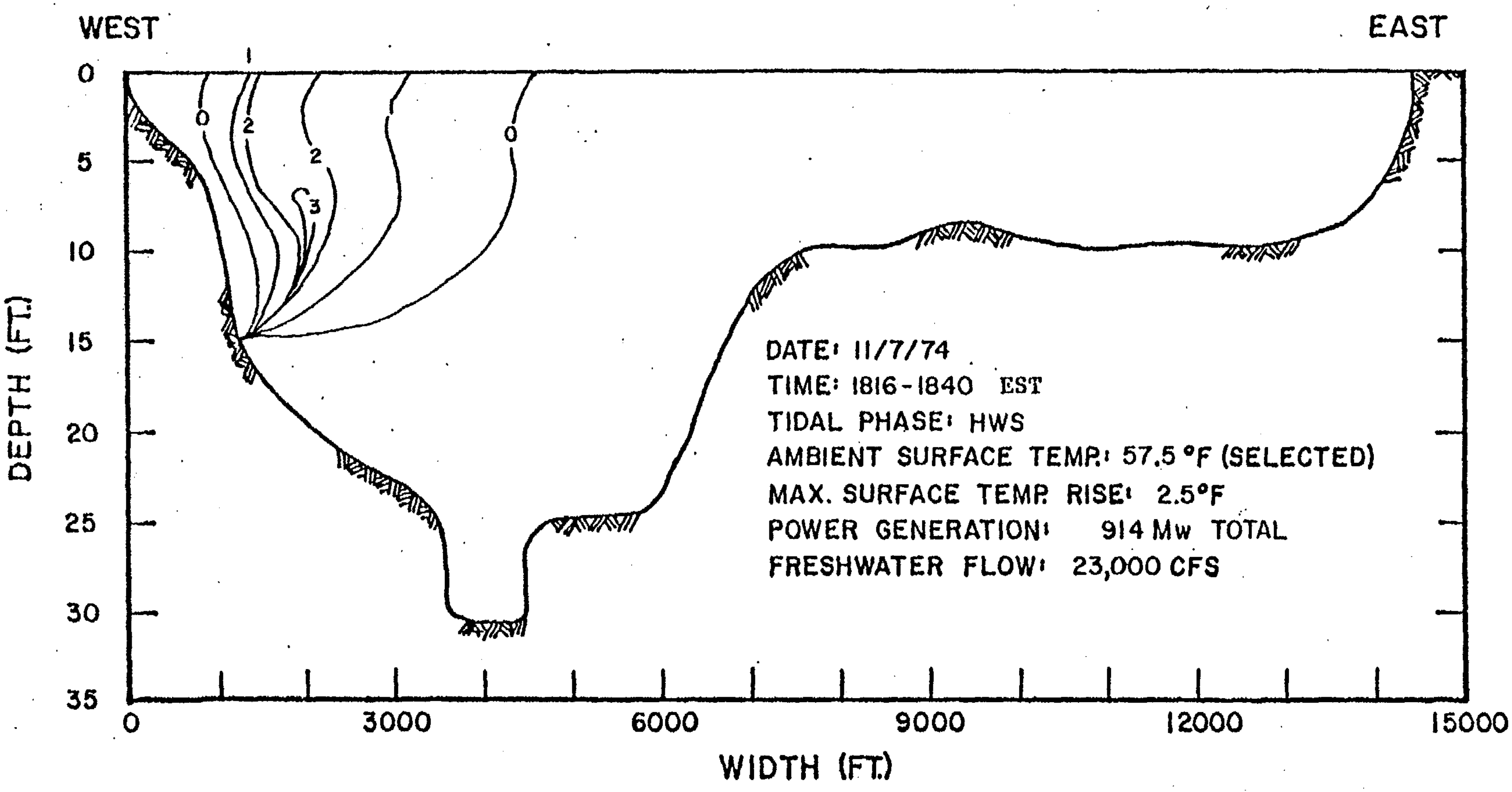
BOWLINE DISCHARGE
CROSS-SECTIONAL TEMPERATURE (°F) DISTRIBUTION
TEMPERATURE RISE ISOTHERMS



DATE: 11/7/74
TIME: 1515-1608 EST
TIDAL PHASE: FLOOD
AMBIENT SURFACE TEMP: 57.0 °F (SELECTED)
MAX. SURFACE TEMP RISE: 5.4°F
POWER GENERATION: 912 Mw TOTAL
FRESHWATER FLOW: 23,000 CFS

FIGURE A-19

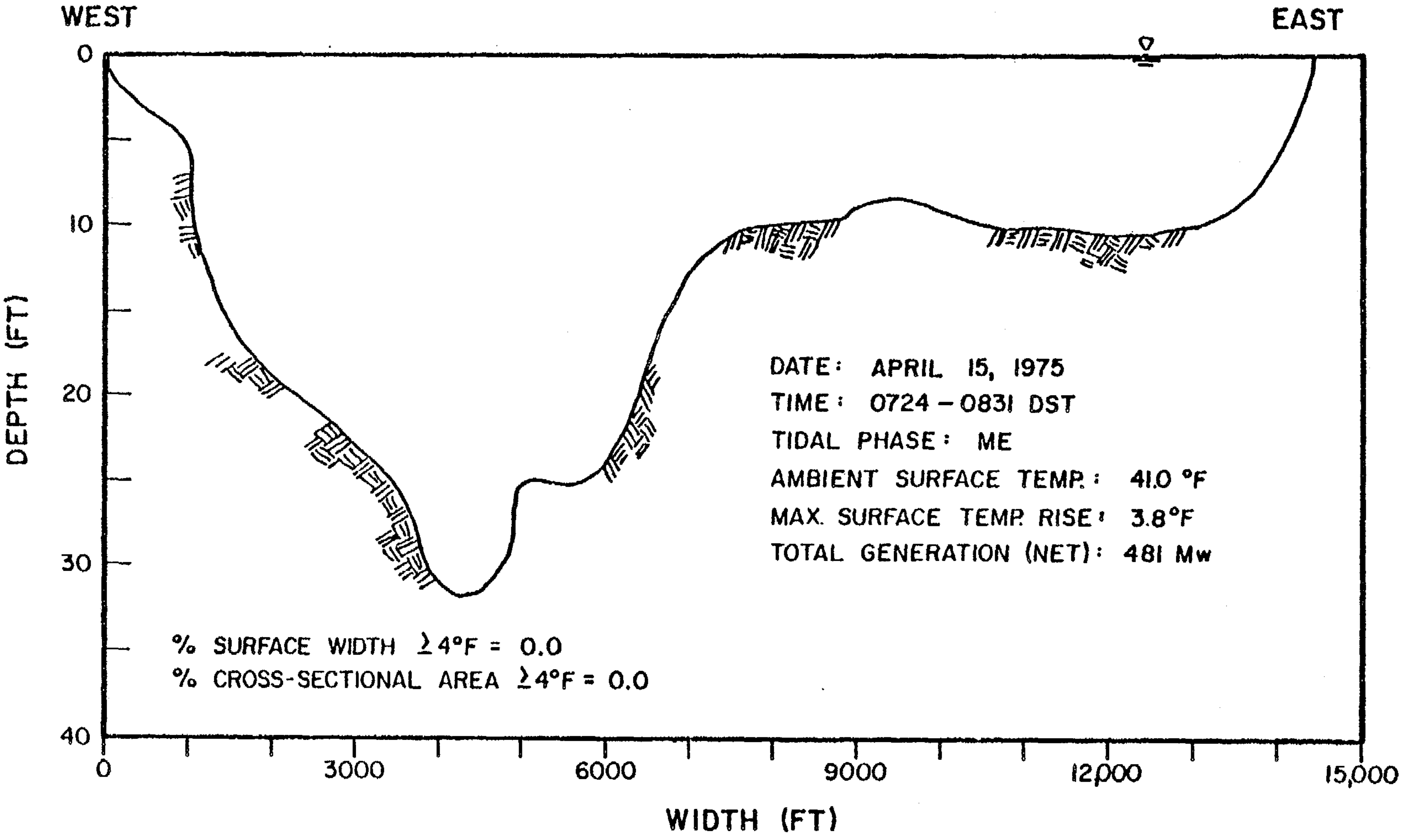
BOWLINE DISCHARGE
CROSS-SECTIONAL TEMPERATURE (°F) DISTRIBUTION
TEMPERATURE RISE ISOTHERMS



DATE: 11/7/74
TIME: 1816-1840 EST
TIDAL PHASE: HWS
AMBIENT SURFACE TEMP.: 57.5 °F (SELECTED)
MAX. SURFACE TEMP. RISE: 2.5°F
POWER GENERATION: 914 Mw TOTAL
FRESHWATER FLOW: 23,000 CFS

FIGURE A-20

BOWLINE DISCHARGE
CROSS-SECTIONAL TEMPERATURE (°F) DISTRIBUTION
TEMPERATURE RISE ISOTHERMS

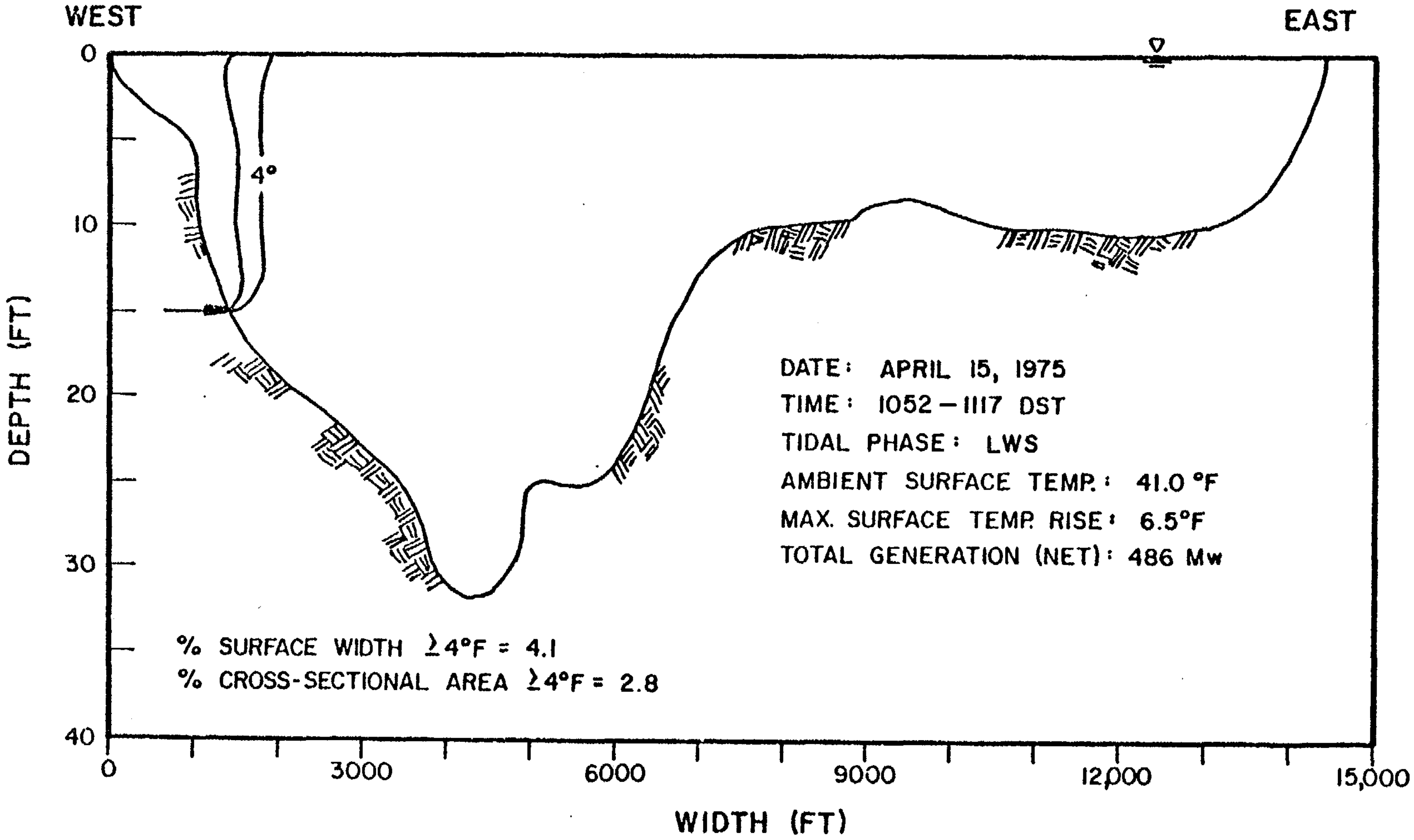


DATE: APRIL 15, 1975
TIME: 0724 – 0831 DST
TIDAL PHASE: ME
AMBIENT SURFACE TEMP.: 41.0 °F
MAX. SURFACE TEMP. RISE: 3.8°F
TOTAL GENERATION (NET): 481 Mw

% SURFACE WIDTH ≥ 4°F = 0.0
% CROSS-SECTIONAL AREA ≥ 4°F = 0.0

FIGURE A-21

BOWLINE DISCHARGE
CROSS-SECTIONAL TEMPERATURE (°F) DISTRIBUTION
TEMPERATURE RISE ISOTHERMS

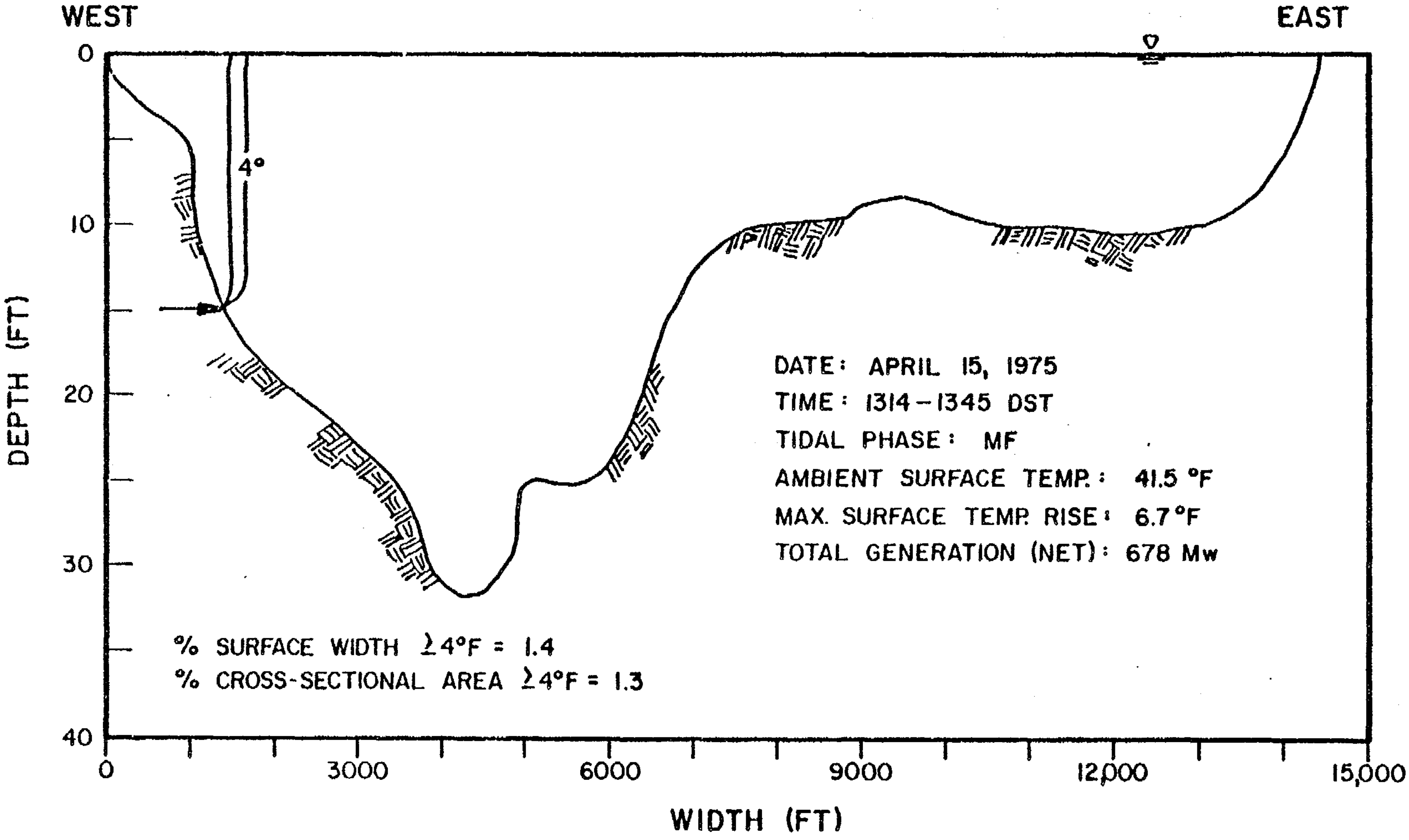


DATE: APRIL 15, 1975
TIME: 1052 – 1117 DST
TIDAL PHASE: LWS
AMBIENT SURFACE TEMP.: 41.0 °F
MAX. SURFACE TEMP. RISE: 6.5°F
TOTAL GENERATION (NET): 486 Mw

% SURFACE WIDTH ≥ 4°F = 4.1
% CROSS-SECTIONAL AREA ≥ 4°F = 2.8

FIGURE A-22

BOWLINE DISCHARGE
CROSS-SECTIONAL TEMPERATURE (°F) DISTRIBUTION
TEMPERATURE RISE ISOTHERMS

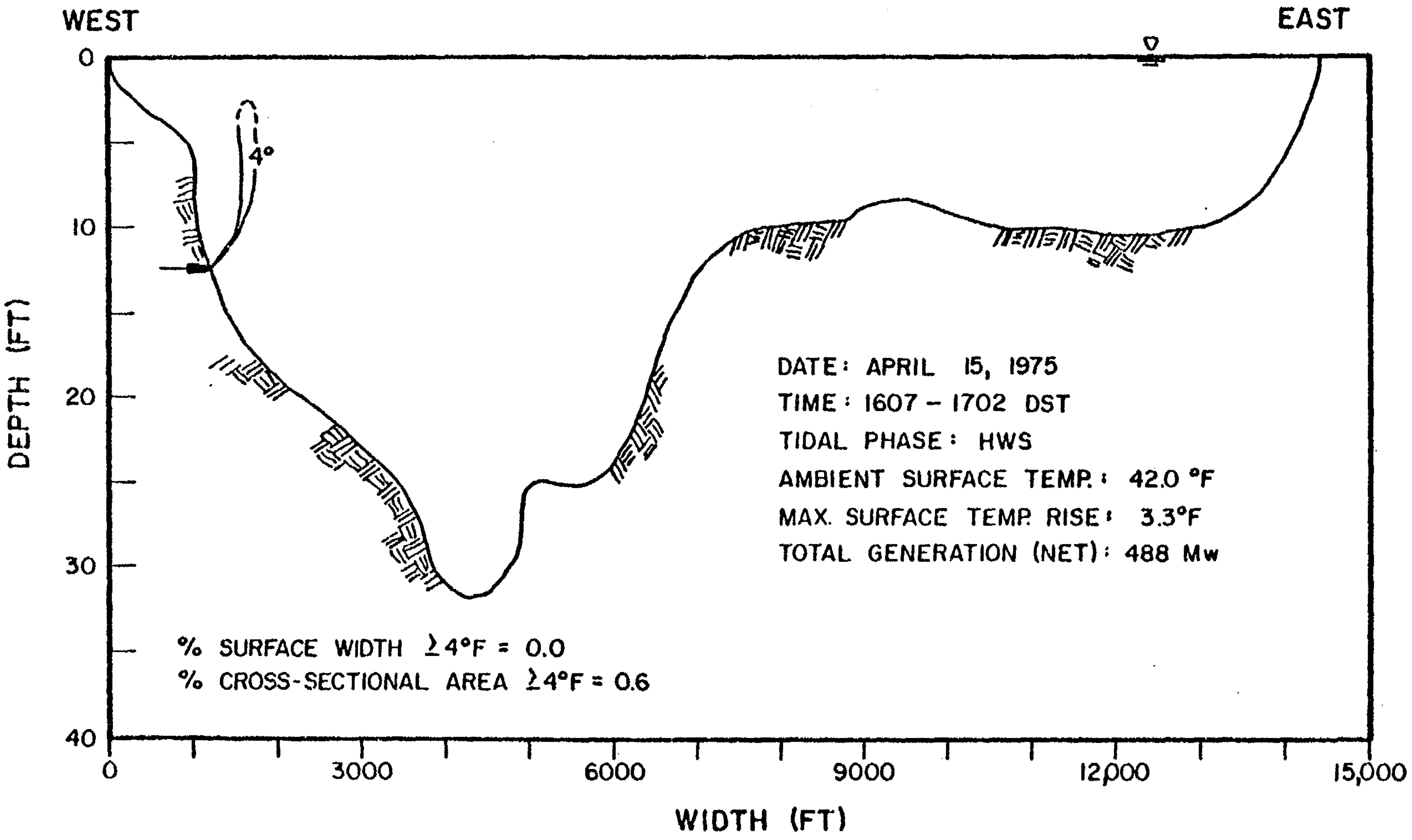


DATE: APRIL 15, 1975
TIME: 1314 – 1345 DST
TIDAL PHASE: MF
AMBIENT SURFACE TEMP.: 41.5 °F
MAX. SURFACE TEMP. RISE: 6.7 °F
TOTAL GENERATION (NET): 678 Mw

% SURFACE WIDTH ≥ 4°F = 1.4
% CROSS-SECTIONAL AREA ≥ 4°F = 1.3

FIGURE A-23

BOWLINE DISCHARGE
CROSS-SECTIONAL TEMPERATURE (°F) DISTRIBUTION
TEMPERATURE RISE ISOTHERMS

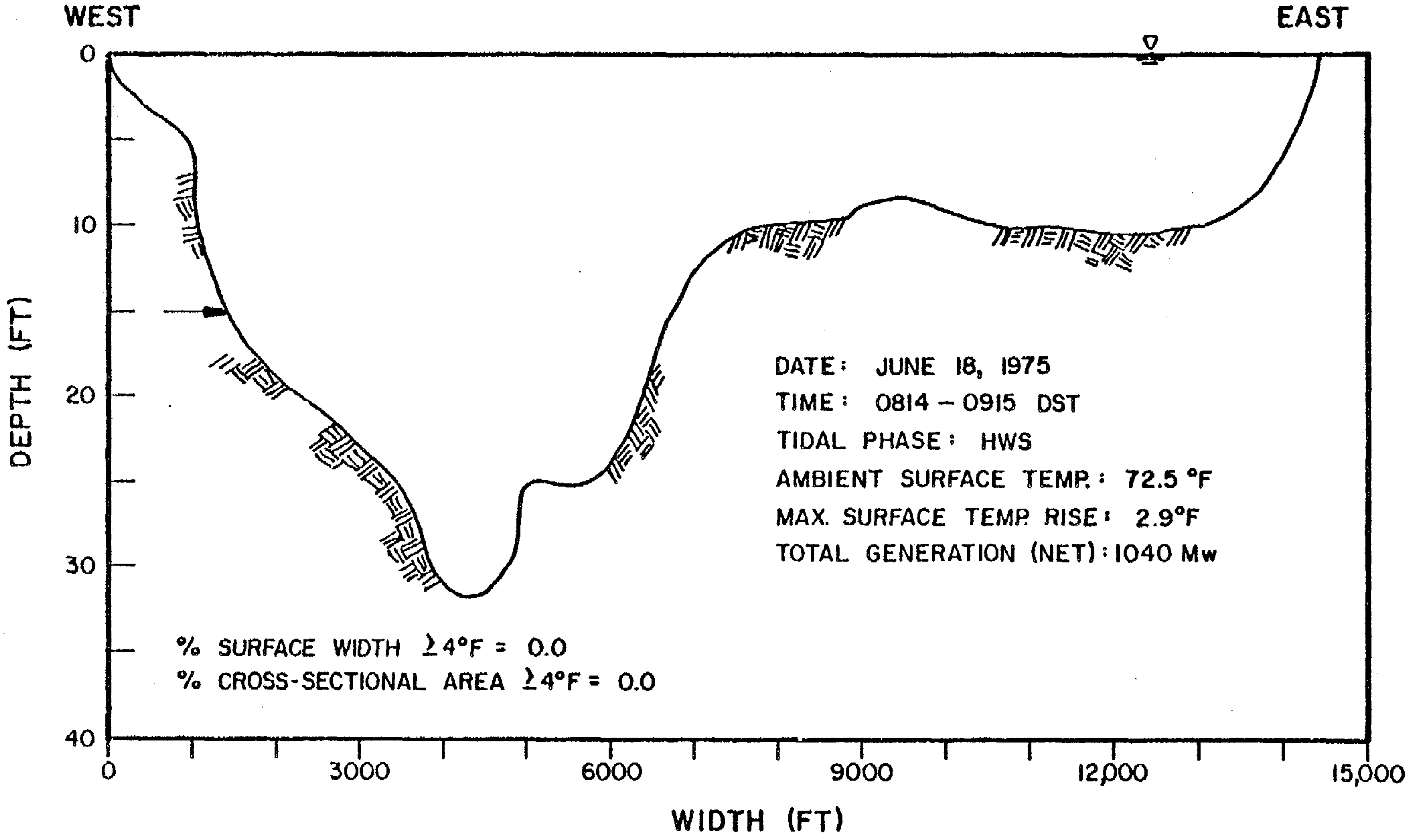


DATE: APRIL 15, 1975
TIME: 1607 – 1702 DST
TIDAL PHASE: HWS
AMBIENT SURFACE TEMP.: 42.0 °F
MAX. SURFACE TEMP. RISE: 3.3°F
TOTAL GENERATION (NET): 488 Mw

% SURFACE WIDTH ≥ 4°F = 0.0
% CROSS-SECTIONAL AREA ≥ 4°F = 0.6

FIGURE A-24

BOWLINE DISCHARGE
CROSS-SECTIONAL TEMPERATURE (°F) DISTRIBUTION
TEMPERATURE RISE ISOTHERMS



DATE: JUNE 18, 1975
TIME: 0814 – 0915 DST
TIDAL PHASE: HWS
AMBIENT SURFACE TEMP.: 72.5 °F
MAX. SURFACE TEMP. RISE: 2.9°F
TOTAL GENERATION (NET): 1040 Mw

% SURFACE WIDTH ≥ 4°F = 0.0
% CROSS-SECTIONAL AREA ≥ 4°F = 0.0

FIGURE A-25

BOWLINE DISCHARGE
CROSS-SECTIONAL TEMPERATURE (°F) DISTRIBUTION
TEMPERATURE RISE ISOTHERMS

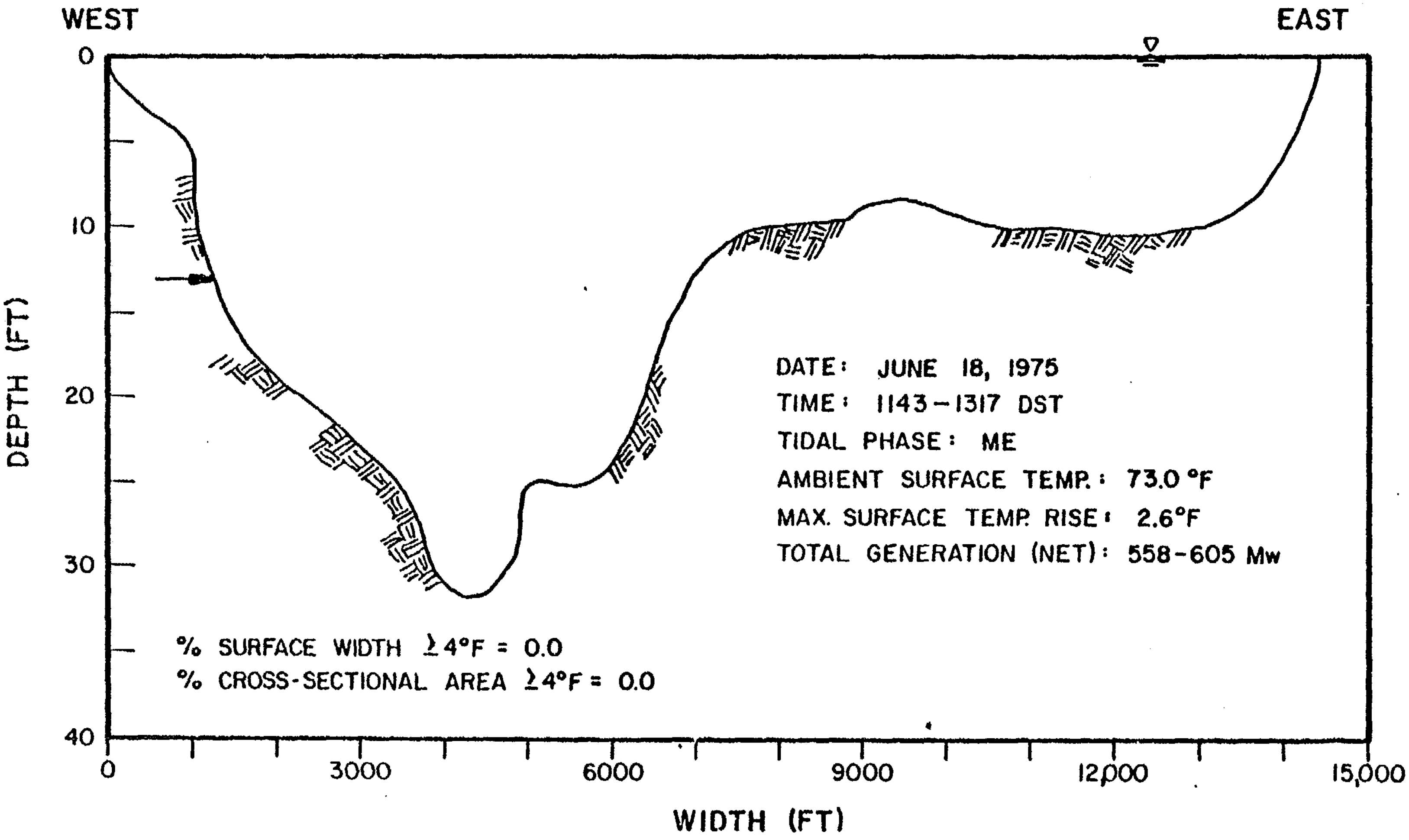
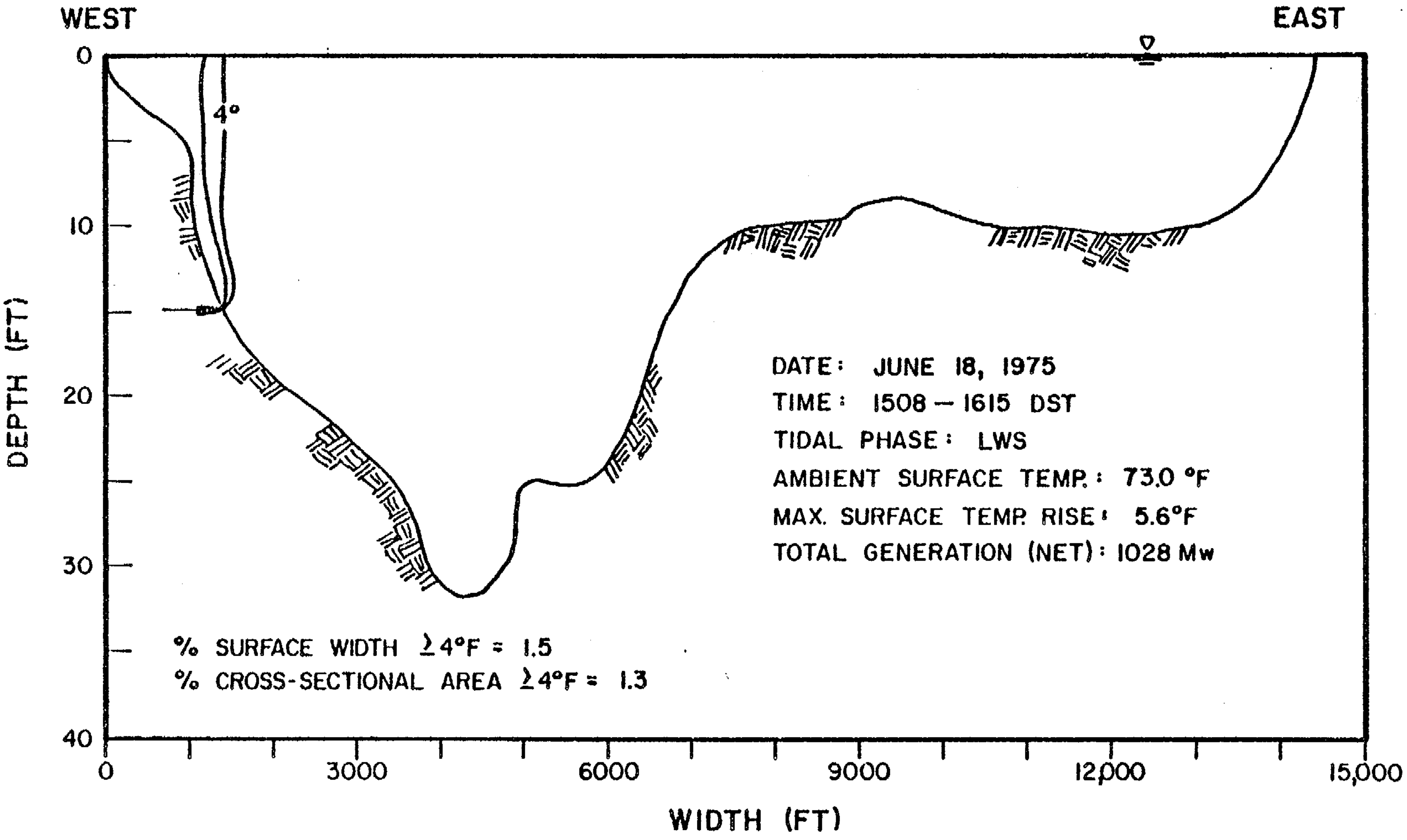


FIGURE A-26

BOWLINE DISCHARGE
CROSS-SECTIONAL TEMPERATURE (°F) DISTRIBUTION
TEMPERATURE RISE ISOTHERMS

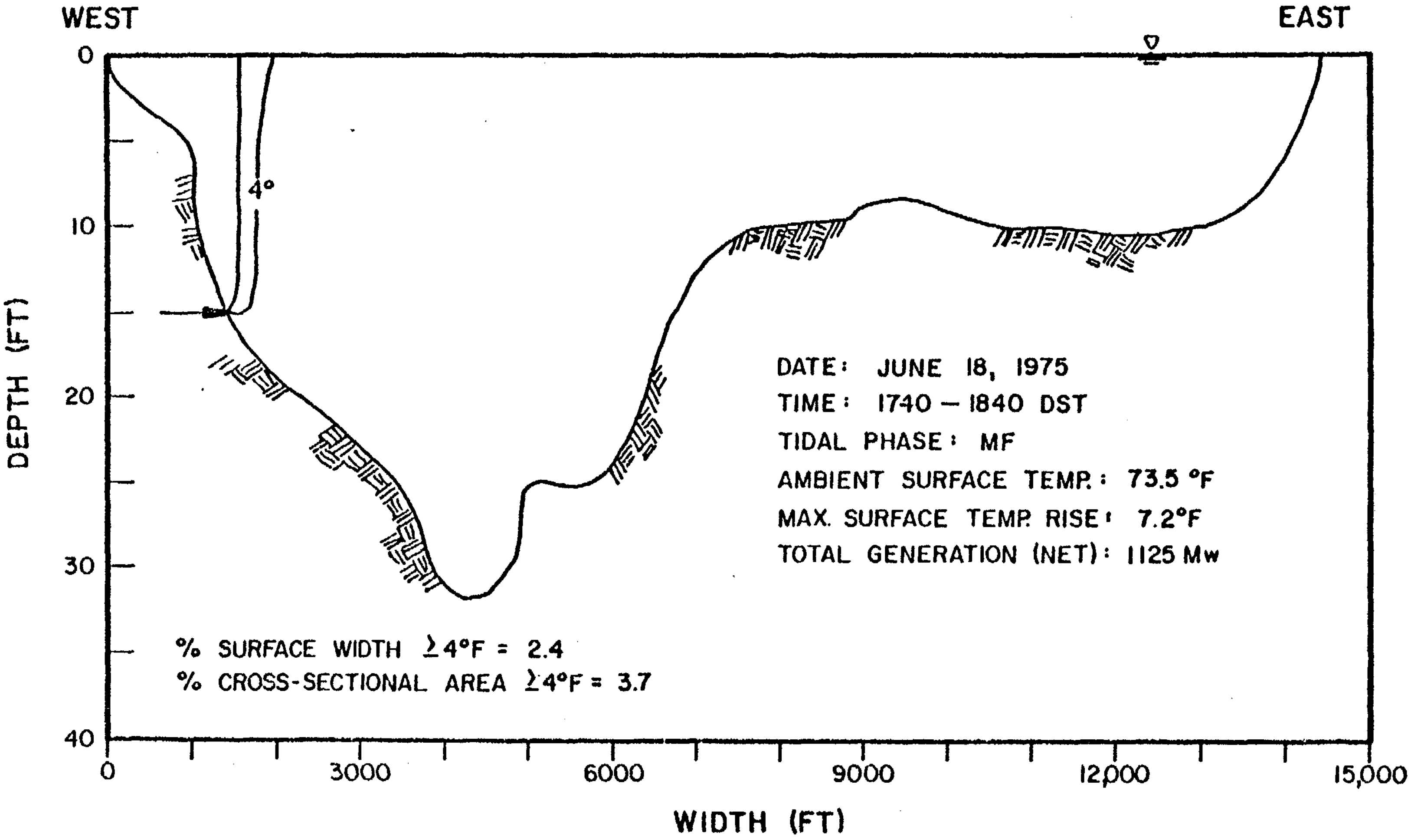


DATE: JUNE 18, 1975
TIME: 1508 – 1615 DST
TIDAL PHASE: LWS
AMBIENT SURFACE TEMP.: 73.0 °F
MAX. SURFACE TEMP. RISE: 5.6°F
TOTAL GENERATION (NET): 1028 Mw

% SURFACE WIDTH ≥ 4°F = 1.5
% CROSS-SECTIONAL AREA ≥ 4°F = 1.3

FIGURE A-27

BOWLINE DISCHARGE
CROSS-SECTIONAL TEMPERATURE (°F) DISTRIBUTION
TEMPERATURE RISE ISOTHERMS

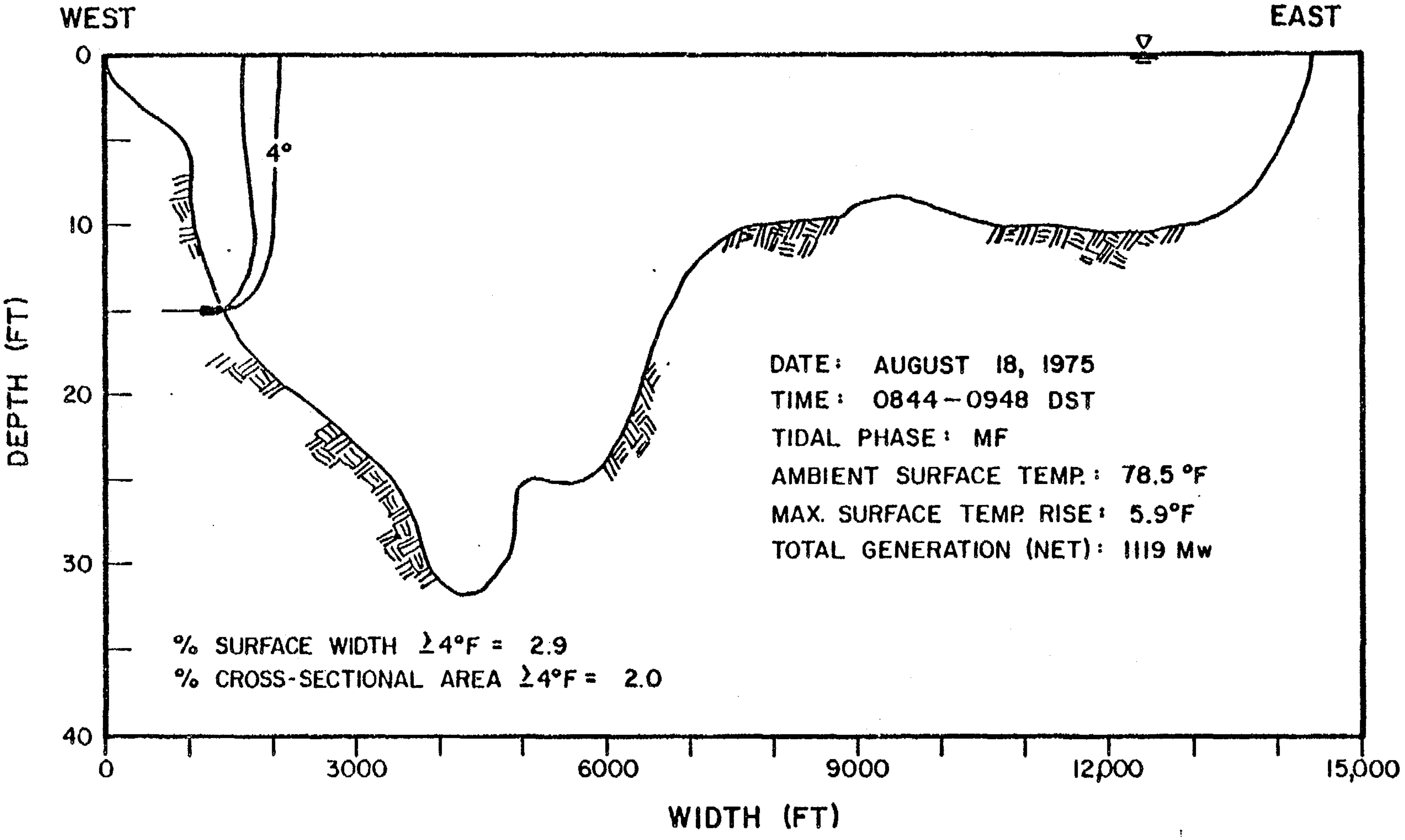


DATE: JUNE 18, 1975
TIME: 1740 – 1840 DST
TIDAL PHASE: MF
AMBIENT SURFACE TEMP.: 73.5 °F
MAX. SURFACE TEMP. RISE: 7.2°F
TOTAL GENERATION (NET): 1125 Mw

% SURFACE WIDTH ≥ 4°F = 2.4
% CROSS-SECTIONAL AREA ≥ 4°F = 3.7

FIGURE A-28

BOWLINE DISCHARGE
CROSS-SECTIONAL TEMPERATURE (°F) DISTRIBUTION
TEMPERATURE RISE ISOTHERMS



DATE: AUGUST 18, 1975
TIME: 0844–0948 DST
TIDAL PHASE: MF
AMBIENT SURFACE TEMP.: 78.5 °F
MAX. SURFACE TEMP. RISE: 5.9°F
TOTAL GENERATION (NET): 1119 Mw

% SURFACE WIDTH ≥ 4°F = 2.9
% CROSS-SECTIONAL AREA ≥ 4°F = 2.0

FIGURE A-29

BOWLINE DISCHARGE
CROSS-SECTIONAL TEMPERATURE (°F) DISTRIBUTION
TEMPERATURE RISE ISOTHERMS

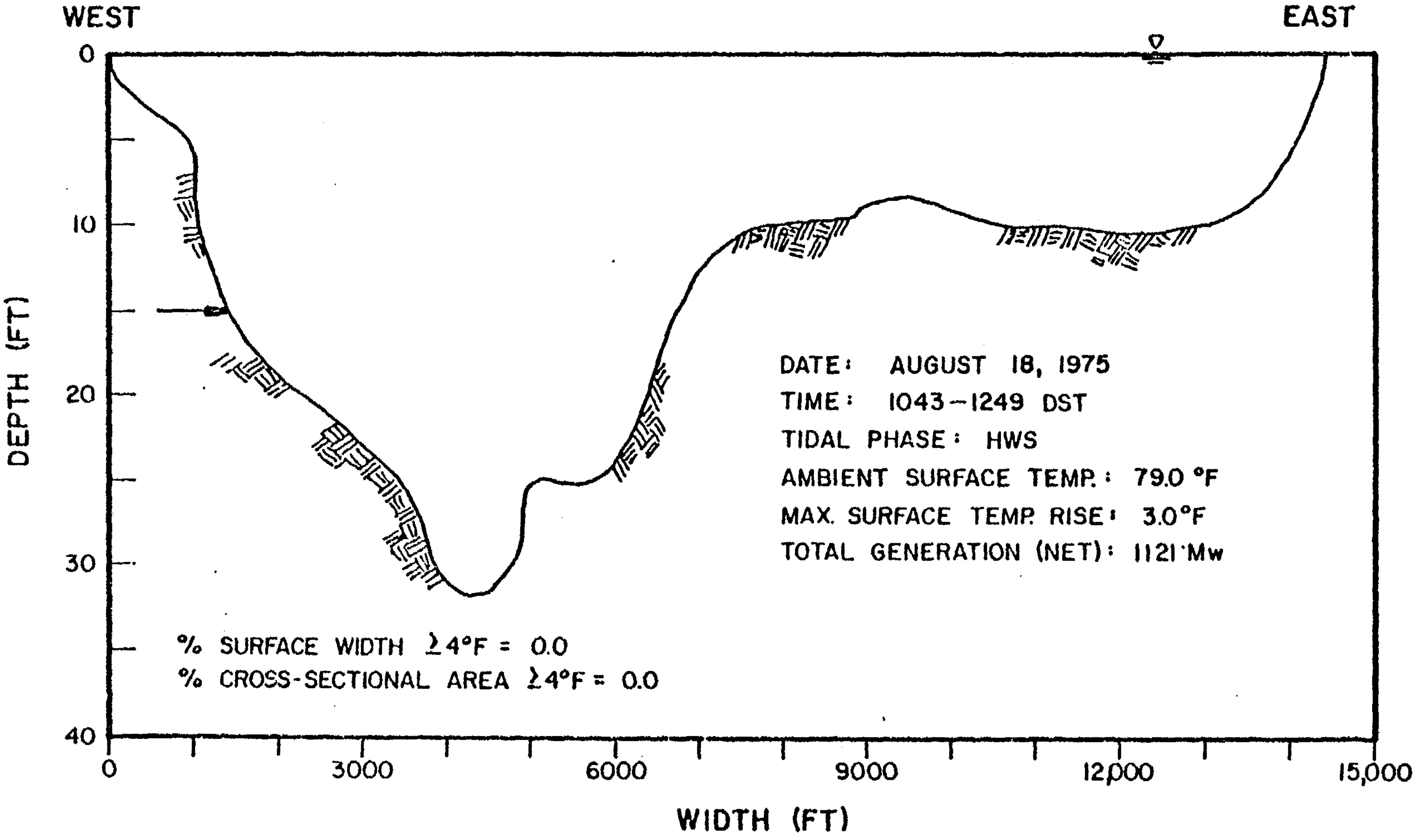


FIGURE A-30

BOWLINE DISCHARGE
CROSS-SECTIONAL TEMPERATURE (°F) DISTRIBUTION
TEMPERATURE RISE ISOTHERMS

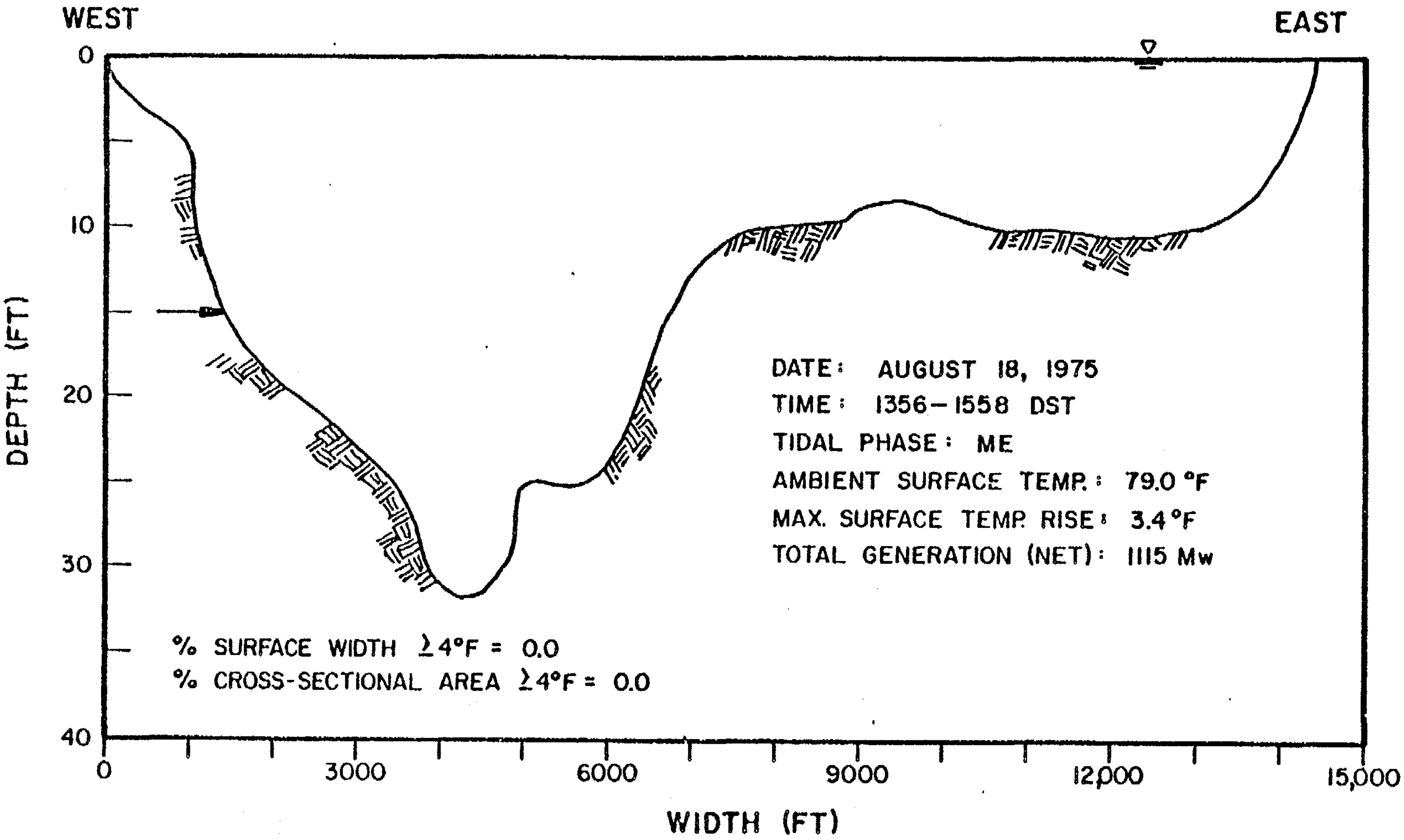
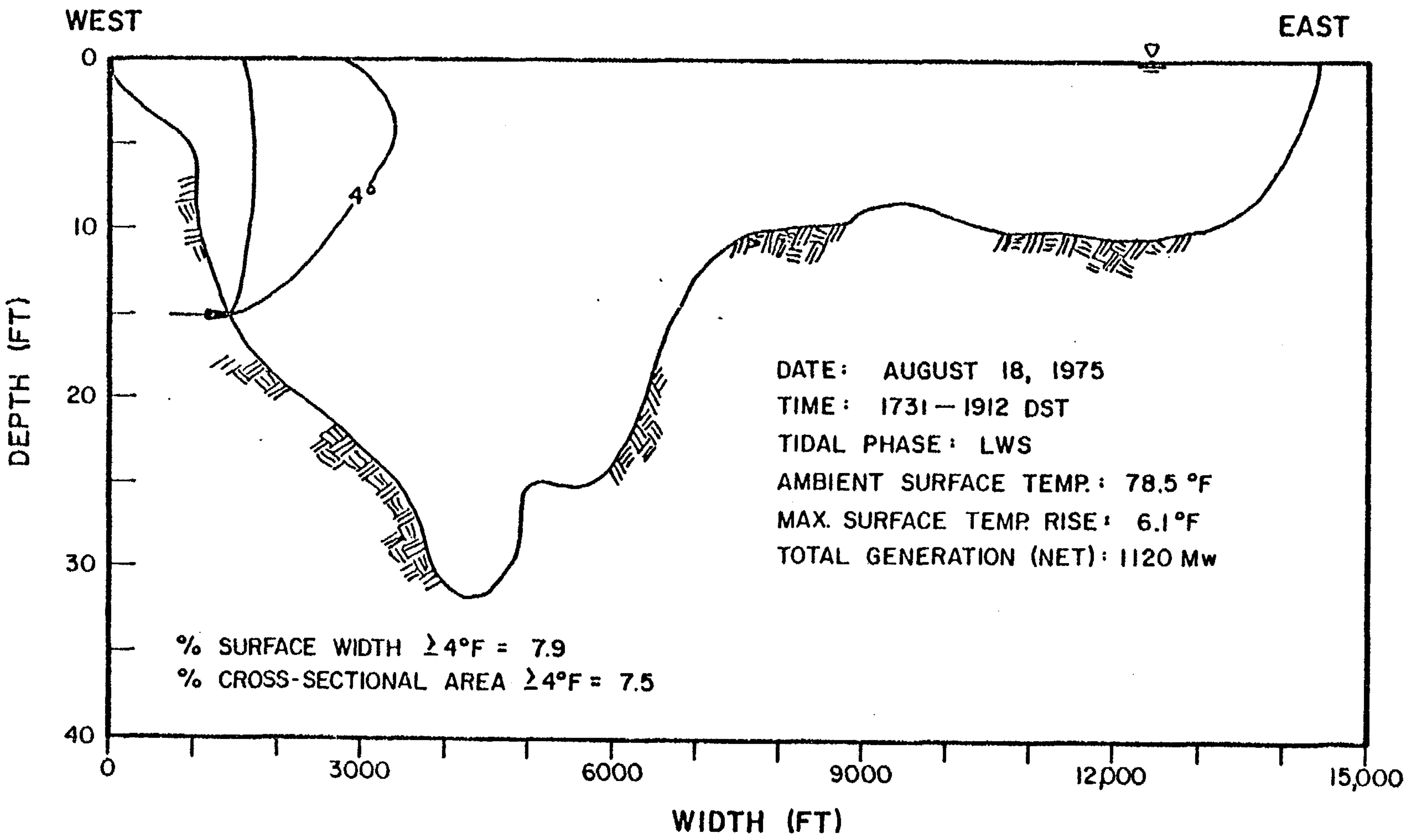


FIGURE A-31

BOWLINE DISCHARGE
CROSS-SECTIONAL TEMPERATURE (°F) DISTRIBUTION
TEMPERATURE RISE ISOTHERMS



DATE: AUGUST 18, 1975
TIME: 1731 — 1912 DST
TIDAL PHASE: LWS
AMBIENT SURFACE TEMP.: 78.5 °F
MAX. SURFACE TEMP. RISE: 6.1 °F
TOTAL GENERATION (NET): 1120 Mw

% SURFACE WIDTH ≥ 4°F = 7.9
% CROSS-SECTIONAL AREA ≥ 4°F = 7.5

FIGURE A-32